Supporting Materials

California Education and the Environment Initiative

E

Earth Science
Standard
E.4.c.

CALIFORNIA
EEI
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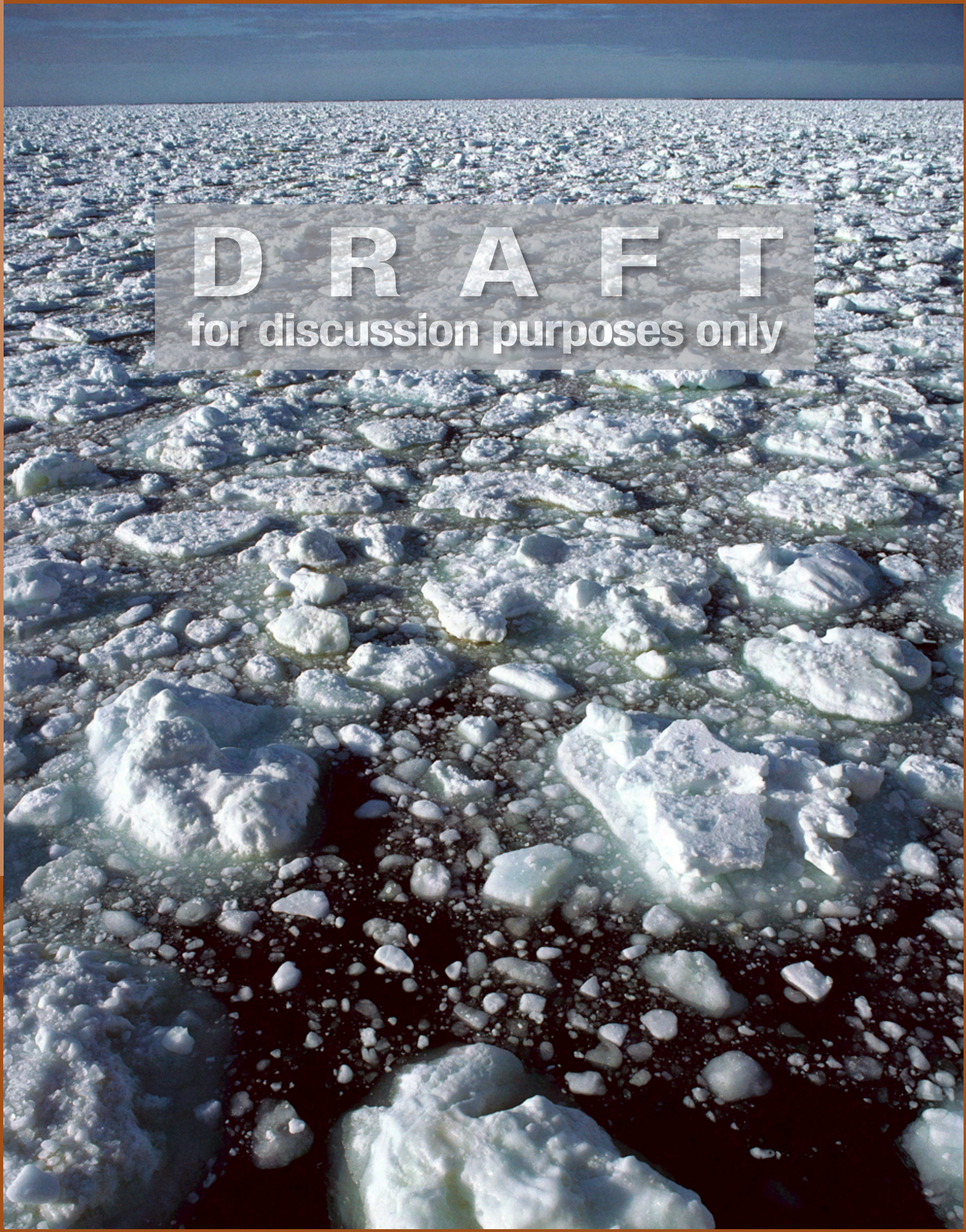

The Greenhouse Effect on Natural Systems

DRAFT
for discussion purposes only

California Education and the Environment Initiative

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Activity Masters

Name: ___________________________

Part 1

Multiple Choice: Select the best answer and circle the correct letter. (2 points each)

1. Which of the following is a source of thermal energy absorbed by Earth's atmosphere?
   a. the Sun
   b. human activity
   c. Earth itself
   d. all of the above

2. Which of the following is not a greenhouse gas?
   a. carbon dioxide
   b. nitrogen
   c. water vapor
   d. methane

3. What is the role of aerosols in the radiation balance of the atmosphere?
   a. liquid or solid particles in aerosols are too small to have any effect.
   b. liquid or solid particles in aerosols are too large to have any effect.
   c. liquid or solid particles in aerosols reflect energy.
   d. liquid or solid particles in aerosols absorb energy.

4. Which best describes Earth without the greenhouse effect?
   a. There would be more ice ages.
   b. There would still be dinosaurs on Earth.
   c. There would be no atmosphere.
   d. There would be no life as we know it.

5. Which of the following is the largest natural source of carbon dioxide in the atmosphere?
   a. respiration by animals
   b. the ocean
   c. permafrost
   b. the ozone layer

6. Which greenhouse gas comes from decomposing plants and animal matter?
   a. nitrous oxide
   b. carbon dioxide
   c. methane
   d. all of the above

Name: ______________________________

7. Which best describes a greenhouse gas sink?
   a. something that takes out and stores greenhouse gases.
   b. an industrial process of removing greenhouse gases from the atmosphere.
   c. a gas that gets into the atmosphere and changes the climate.
   d. something that releases greenhouse gases when it burns.

8. Which is true about forests?
   a. Without them, there would be no greenhouse effect.
   b. They are both a source and sink of carbon dioxide.
   c. They absorb CFCs from the atmosphere.
   d. They were not around during the ice ages.

9. Which of the following is a result of the greenhouse effect?
   a. the climate
   b. carbon dioxide in the atmosphere
   c. global warming
   d. a and c

10. All of the following are probable results of global climate change except:
    a. changes in average seasonal temperatures
    b. changes in the amount of snow, polar ice, and glaciers
    c. more supervolcanic eruptions
    d. extinction of some organisms

Part 2

Short Answer: Provide a short answer for the following questions. (5 points each)

11. What is Earth's natural greenhouse effect on the atmosphere and how does it work?

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12. How does the greenhouse effect relate to climate?

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Name: ______________________________

13. Explain how scientists are studying Earth's past climate. Why are they relating past climate to greenhouse gases?

14. Describe at least two things humans do that affects greenhouse gases in the atmosphere and how those things can affect Earth's climate.

15. What decisions have people made related to climate change and how do those decisions affect human practices (what people should and shouldn't do)?

Name: ______________________________

The producers of a popular TV game show are asking for your help. The theme of an upcoming show is: The Greenhouse Effect and Natural Systems. The producers need your help in writing questions and answers they can use with contestants during the game. The producers will decide how much each question and answer is worth—all you have to do is come up with three good questions that will challenge the contestants on what they know about each category.

Here is the game board so far, with the categories named:

GHGs and the GHE	Sources and Sinks of GHGs	Human Influence on GHGs and Sources/Sinks	GHGs and Climate Change	Climate Science, Law, and Policy

With your 15 index cards, write three questions for each of the five categories. (Each question and answer should have its own card.) Write the question on the front of the card and the answer on the back. Make sure you identify which category each of your cards belongs to. For example:

Front	Back
Your question here	**Answer goes on back**

Name: ______________________________

You may use all of your work from this unit's lessons on the greenhouse effect and natural systems to help you create good questions (and answers) to challenge the contestants.

Your game cards are due at the end of class. Good luck!

For Teacher Use

Score/grade on this assignment: ______________________________

Comments: ______________________________

Absorption: The process of taking in and not reflecting something such as a light ray or radiation.

California Air Resources Board (CARB): The state agency that works with the public, the business sector, and local governments to protect the public's health, the economy, and the state's ecological resources through the most cost-effective reduction of air pollution.

Carbon footprint: The total amount of carbon gases produced to directly or indirectly support human activities.

Climate: The prevailing weather conditions in a region over a long time period as influenced by temperature, precipitation, humidity, and other meteorological factors.

GHG Sink: Any process, activity, or reservoir that absorbs a greenhouse gas from the atmosphere and stores it.

GHG Source: Any process, activity, or reservoir that releases a greenhouse gas into the atmosphere.

Global climate change: A long-term significant change in the Earth's climatic patterns.

Global warming: The gradual increase of the overall temperature of Earth's atmosphere caused in part by increasing levels of atmospheric carbon dioxide from the burning of fossil fuels.

Greenhouse effect: The combined effect of certain gases in the atmosphere absorbing infrared and thermal radiation, affecting the overall temperature of Earth.

Greenhouse gas (GHG): Any gas, such as water vapor, carbon dioxide, chlorine, or methane that absorbs infrared radiation in the atmosphere and contributes to the greenhouse effect.

Infrared radiation: Electromagnetic radiation not visible to the eye ("below red" in the visible portion of the spectrum), measured as heat or thermal energy.

Paleoclimatology: The study of past climate and its causes and effects.

Proxy data: Information used "in place of" direct evidence to draw conclusions. Proxy data includes data from fossils, sediments, ice sheets, and tree rings.

Reflection: The process of scattering or bouncing back something such as a light ray or radiation.

Thermal radiation: Electromagnetic radiation emitted as heat by a warm body.

Weather: State of the atmosphere (temperature, moisture, wind and other atmospheric conditions) at a given time and place.

Climate Change in the Golden State

The Earth has experienced natural climate changes since the planet formed billions ago. Many of these climate changes have been slow, occurring over centuries or millennia. Subtle differences in Earth's orbit around the Sun, or shifting landmasses (for example, moving tectonic plates or the uplift of mountain ranges) cause these slow climatic changes. Rapid changes in climate, those that happen over decades or even a few years, are triggered by sudden events, such as volcanic eruptions, collisions with meteors, or drastic shifts in ocean currents.

Climate change is a shift in the "average weather" that a given region experiences. This is measured by changes in the features we associate with weather, such as temperature, wind patterns, precipitation, and storms. Global climate change means change in the climate of the Earth as a whole. Global climate change can occur naturally; an ice age is an example of naturally occurring climate change. The Earth's natural climate has always been, and still is, constantly changing. The climate change we are seeing today, however, differs from previous climate change in both its rate and its magnitude.

Global warming occurs when greenhouse gases are released on the planet, where they build up in the Earth's atmosphere.

Snow melting in Sierra Nevada Mountains

This forms a layer in the upper atmosphere that allows heat and light in; then some of the heat/light energy stays near Earth's surface, and the rest, escapes out into space. Without the effect of these naturally occurring gases, the average temperature on the Earth would be -0.4° F, instead of the current average 60° F. Life as we know it would be impossible.

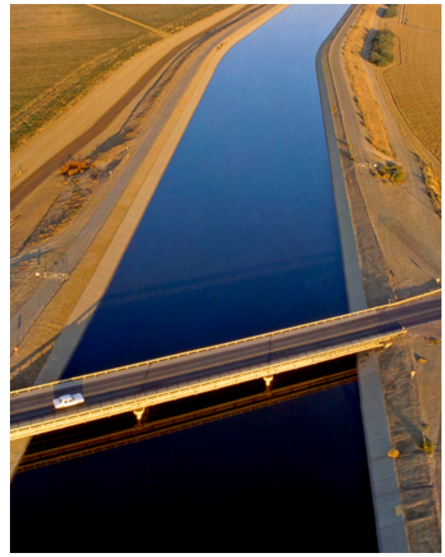
The last 10,000 years has been a warm and stable period, and the last millennium, over which current societies have developed, has been one of the most stable climates observed. Yet, during the 20th century, we have observed a rapid change in the climate and atmospheric concentration of greenhouse gases attributable to human activities. These recent changes in greenhouse gases far exceed the extremes of the ice ages, and the global mean temperature is warming at a rate that cannot be explained by natural causes alone. The natural archives of Earth's climate, such as fossils, ocean sediments, and ice cores, record global temperature fluctuations that have resulted in ice ages and warm periods. During the last ice age, Earth was approximately 10° F (5.6° C) cooler than it is now. Sheets of ice a mile thick covered the poles and the northern United States. Now we are in a warm period. The global temperature has risen almost 2° F (1.1° C) in the last century. And the rate of warming seems to be increasing.

Changes in California's own climate are in line with the warming trends in many other places. Our winter and spring temperatures have risen steadily in the last 50 years. This rise has caused the snowpack in the Sierra Nevada Mountains to melt earlier every spring. Even the wildflowers bloom two weeks earlier. Scientists predict that if the warming trend continues, the state's temperatures will rise as much as 10.5° F (5.8° C) by 2100. This increase will put a great deal of extra stress on both the people and natural systems of California.

People living in California already experience the worst air quality in the nation. The air quality in Los Angeles and the San Joaquin Valley will worsen even more if temperatures continue to rise, leading to at least 75 percent more smoggy days. Smog forms just above Earth's surface when heat from the Sun reacts with industrial pollutants and motor vehicle exhaust. This unhealthy air can cause allergies, asthma, and other serious medical conditions.

In January 2007, the National Oceanic and Atmospheric Administration (NOAA) announced that 2006 was the warmest year on record in the United States. In 2006, NASA confirmed that 2005 was the warmest year recorded in human history. People can become seriously ill from intense heat. Elderly people, young children, and people who are already sick are at the greatest risk for heat-related dehydration, heat strokes, heart attacks, or strokes.

Most of the rain and snow that falls in California falls in the northern part of the state. The greatest demand for water, however, comes from drier Southern California, home to two-thirds of the state's population. A system of reservoirs, aqueducts, and pipelines move massive amounts of water to the crowded cities



California Water Project

of the Los Angeles Basin. This water comes from melting snow in the Sierra Nevada Mountains each spring.

If the climate continues to warm, more precipitation will fall as rain, and less will fall as snow. The snow that does fall will melt sooner. The snowpack could decrease by 70–90 percent by the year 2100. This loss of snow would cause huge problems for the people who manage the state's water resources. If not enough water is stored in the winter, people may not have enough drinking water or water for agriculture. Without enough water to flow through dams, power operators might not be able to generate as much electricity. Without lots of snow, winter tourism (including skiing) would decline, causing hard times for snow-related businesses.

Climate change will also affect California's agriculture, which is regarded as one of the world's most productive and diverse growing regions. California produces 50 percent of the nation's fruits, vegetables, and nuts. If climate change continues, the state could experience severe drought. Many fruit and nut trees would not produce good crops if they were exposed to extreme heat. In order to develop healthy buds, these trees need "chill hours" with temperatures below 45° F (7.2° C). Loss of these cold conditions and the greater number of hot days could mean a great loss for California farmers.

Warming temperatures would also increase the number of pests and the frequency of plant diseases that affect California crops. Pest breeding seasons would become longer and pests that like warmer weather will spread to new areas. For example, a certain type of leafhopper, the glassy-winged sharpshooter, spreads Pierce's disease when they eat grape leaves. Pierce's disease is a bacterial disease that destroys the grapevines. These leafhoppers love hot, dry weather, so they would prosper with rising temperatures, leaving vineyard owners in Northern California to deal with an increase of this damaging disease.

Rising temperatures, hot winds, and drought conditions could cause a 55 percent increase in destructive wildfires. Low-intensity fires actually help regenerate certain ecosystems. They clear woody debris and underbrush, release nutrients into the soil, crack open heat-dependent seed coats, and allow light to penetrate through thick foliage. When people do not allow low-intensity fires to burn, fuel sources like underbrush build up. Earth's warming trend could spark intense firestorms from this underbrush, destroying property and wildlife habitat. These fires could also cause the disappearance of plant and animal species in ecosystems already affected by human activity. Wildfires have also severe consequences for human health because they can cause air pollution to spike to unhealthy levels across a broad area.

Climate change already affects California's native trees and plants. Warmer weather in the north is causing cold-loving Douglas firs to die off. Drought-resistant madrone and oak are taking the place of these firs. Nonnative grasses are replacing burned out forests with dry weeds that can spark dangerous fires. In the Sierra Nevada, the fragile plants that make up the alpine tundra are receding to

Forest fire

Storm surge

higher and higher elevations. Scientists predict these plants will decline 60–80 percent by the end of this century.

Future effects would include an increase in extreme heat days, additional rise in sea level, significant loss of snowpack, and increases in forest fires and energy use. The magnitude of these effects depends on the temperature increase. Perhaps the greatest effect of climate change in the future will be felt along the coasts of California. Known for its beaches and recreation, the state attracts people from all over the world. During the last 100 years, sea levels along the California coast have risen seven inches. As Earth continues to warm, sea levels could rise as much as 35 inches by the year 2100. Inland areas will flood with sea water, breaching levees and degrading freshwater supplies for drinking. Animal and plant habitat would also change, causing many species to move out of the area or disappear entirely. Severe storms, pushed inland by high winds, can erode beaches and cause billions of dollars of damage to property, water supplies, utilities, and businesses.

The natural systems of California have seen many climate changes. For example, the La Brea Tar Pits formed many thousands of years ago, trapping plant matter and animals that were part of the ancient Los Angeles ecosystem that existed during the last ice age (more than 10,000 years ago). The 3.5 million fossils collected in the Tar Pits provide a glimpse of life before California's ancient native plants and animals had to either adapt to a different climate, or become extinct. The giant sequoia and the now-endangered California condor both survived this period. The question is: will we survive the changes of the future? The better we understand the causes and effects of climate change, the better we can predict how Earth will be affected. This understanding is key to our planetary and personal survival as the global climate continues to change.

The challenge of ensuring clean air and a healthy climate can be met. Choices made by businesses, communities, and individuals can lead to meaningful reductions in air pollutants and greenhouse gas emissions. Home energy improvements, tree planting programs, alternative transportation, and increased use of public transit are just some of the choices that can be acted upon at the community level. In many cases, one action will reduce both air pollutants and greenhouse gas emissions. Some actions can even save money. Actions taken now and continued over the long-term can make a huge difference in ensuring clean air and a healthy climate for California.

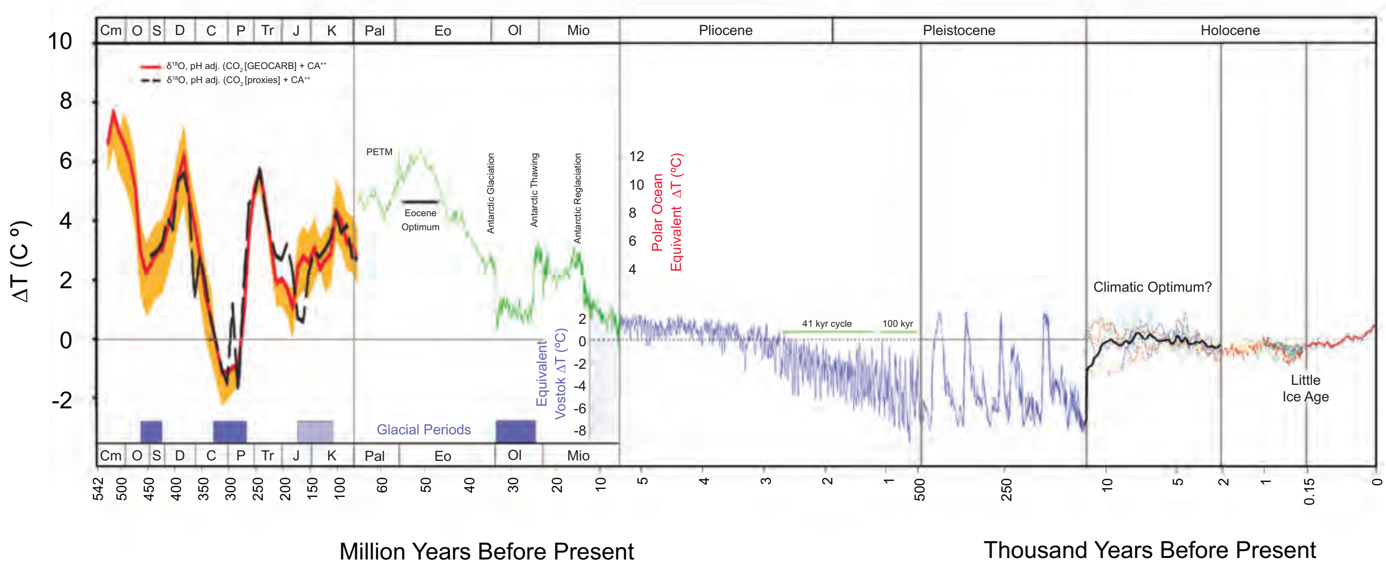
Name: ______________________________

The table below shows how temperatures on Earth have changed during the past 542 million years.

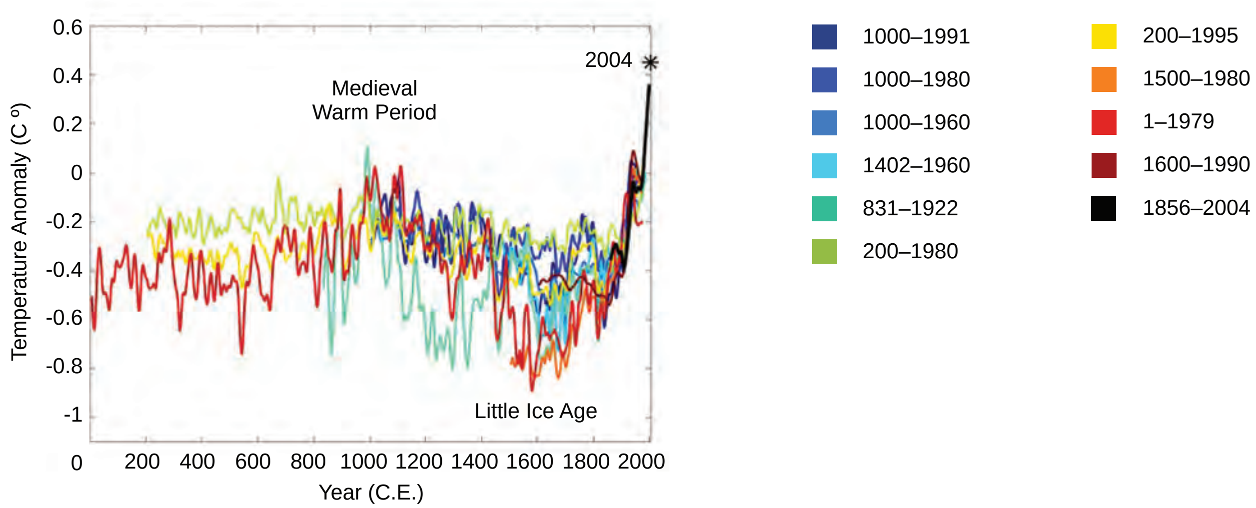
"Temperature Anomaly" and "∆T" mean the same thing (∆ stands for "change in" and T stands for "temperature"). Both of these graphs show how much the temperature changed at a certain time, not the actual temperature at that time.

As you can see, temperatures on Earth have changed many times over millions of years. The smaller graph shows a more detailed view of temperature changes during the past 2,000 years on Earth.

Temperature Change on Earth over Time



Reconstructed Temperature



Name: ______________________________

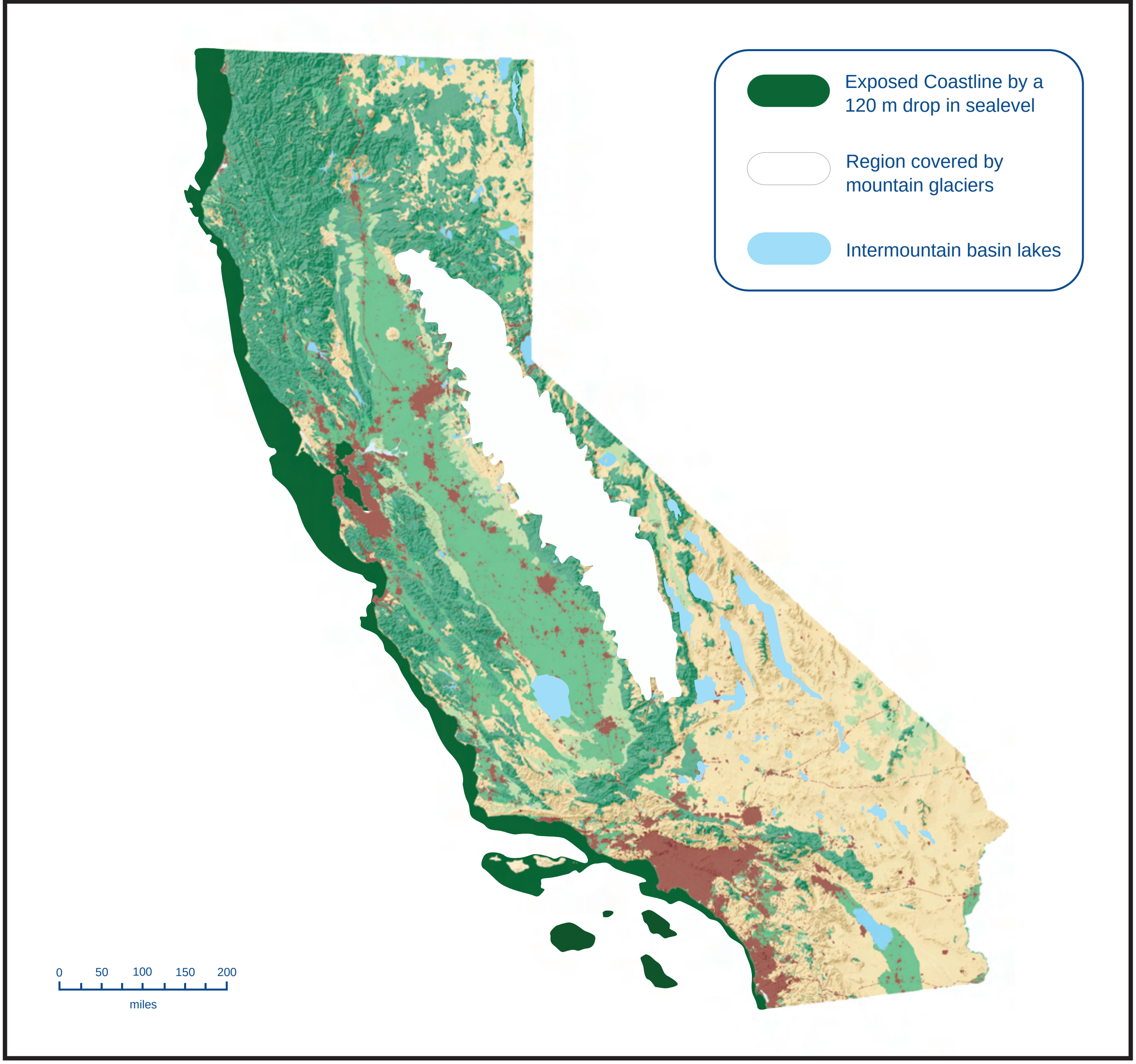
Think and Write

Consider how climate has changed in the past and the fact that climate is continuing to change. How could life be different in the future? What are some of the issues people need to consider when examining climate change?

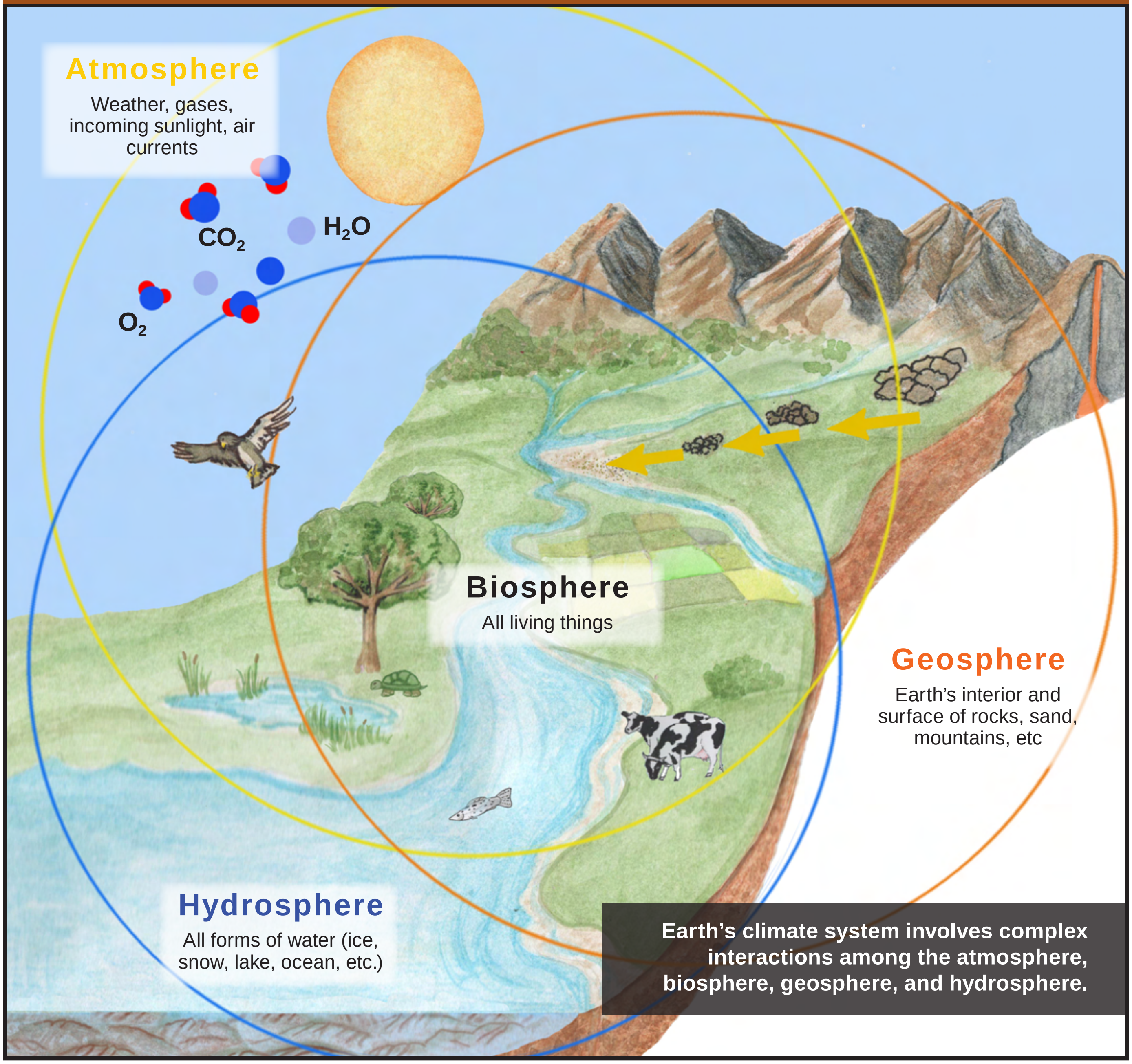
Use information from ***California Connections: Climate Change in the Golden State*** and the graph on the previous page and to develop your answer.

Write your essay below.

California 18,000 Years Ago

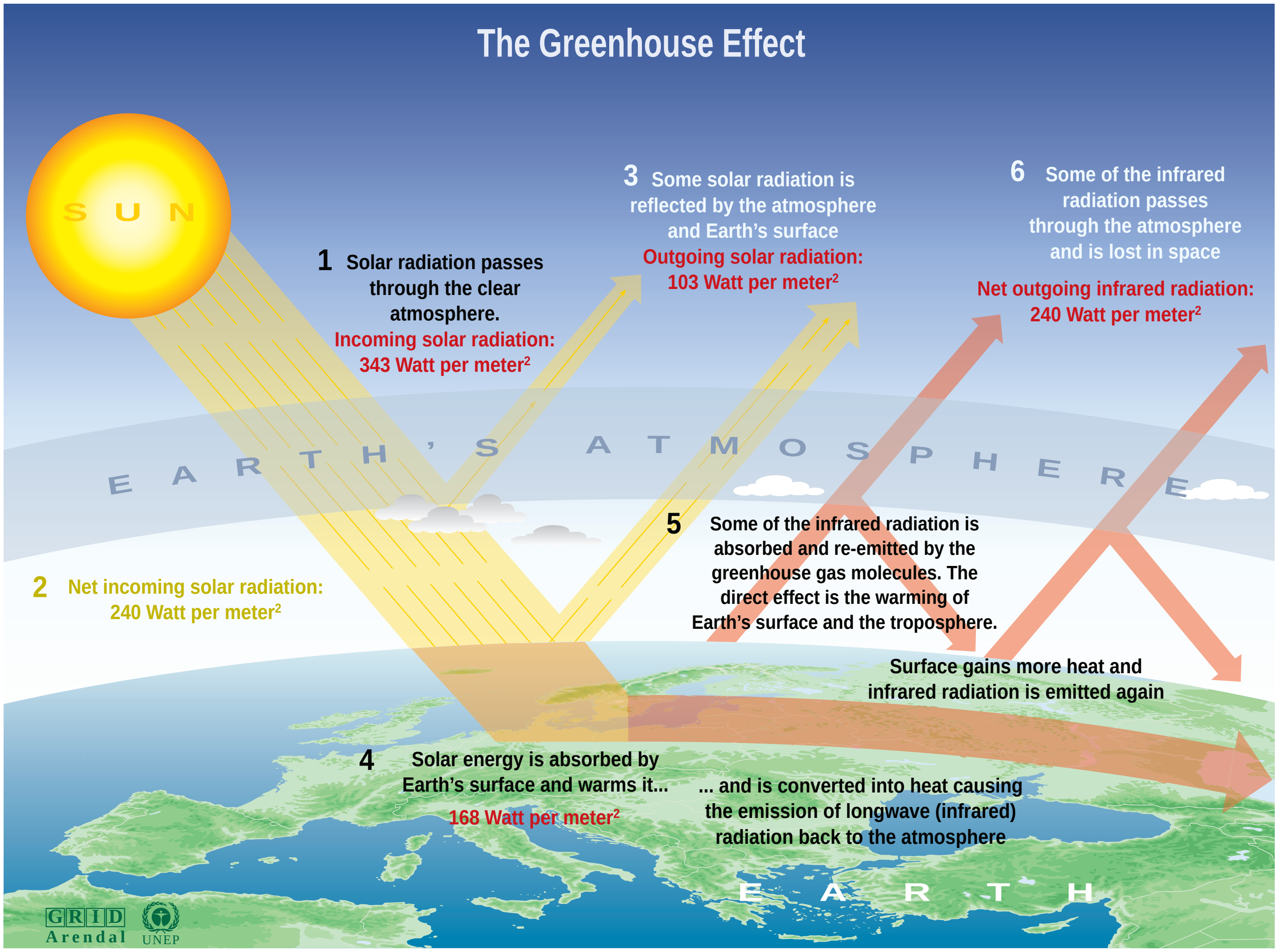


Earth's Climate System



Name: ______________________________

Assignment: Answer the following questions. Use the back of the paper, if you need to. (5 points each)



1. Describe how certain gases in the atmosphere (carbon dioxide, methane, water vapor, and nitrous oxide) influence Earth's thermal radiation, and how those responses affect Earth's atmosphere.

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Name: ______________________________

2. Explain what the "greenhouse effect" is and how it affects temperatures on Earth.

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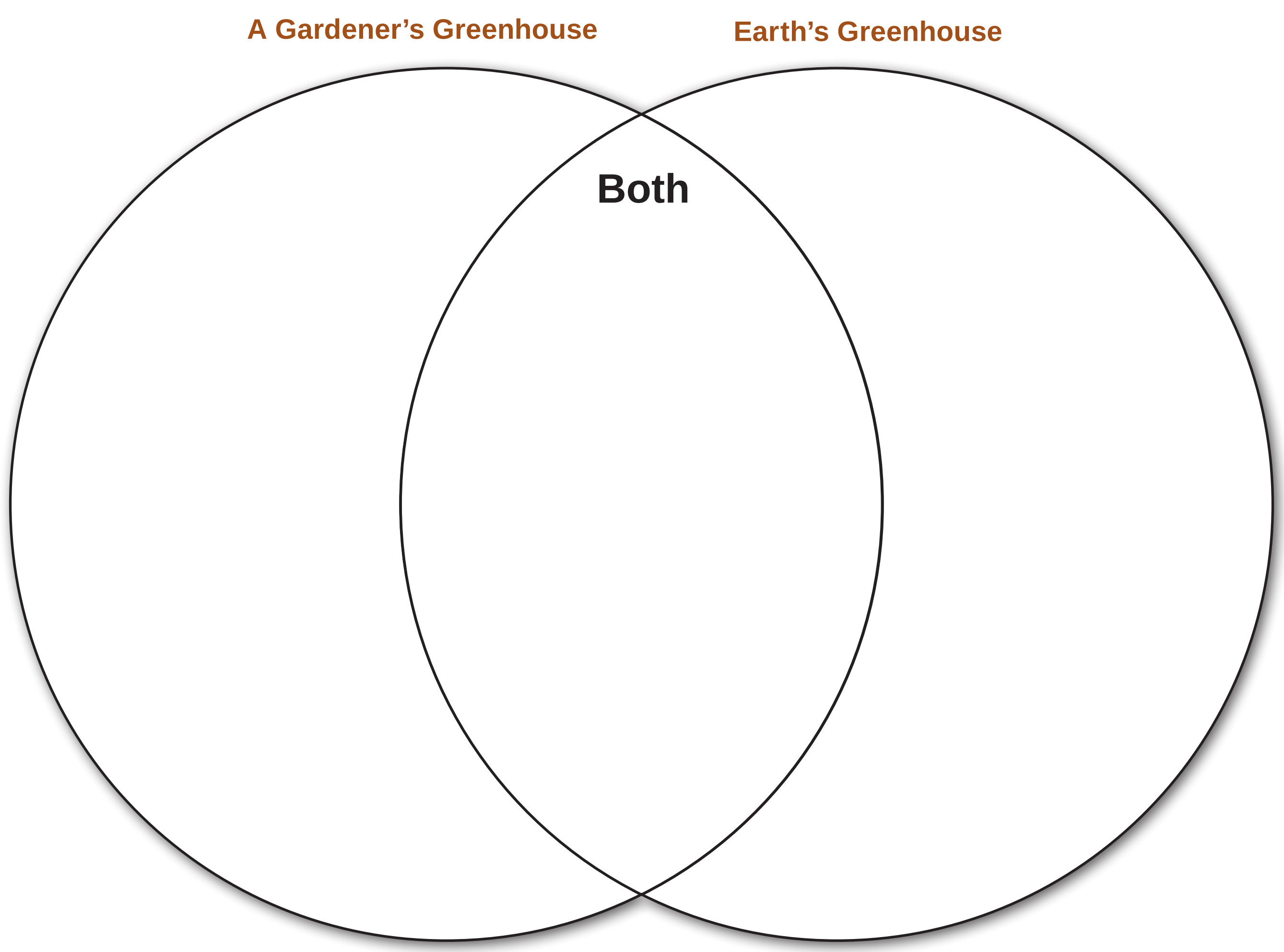
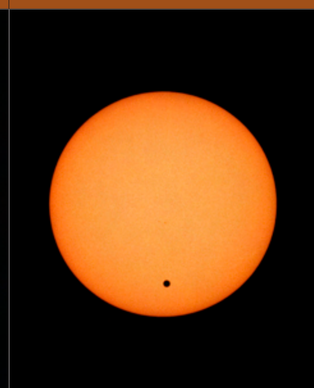
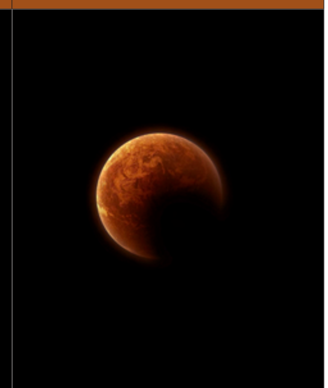
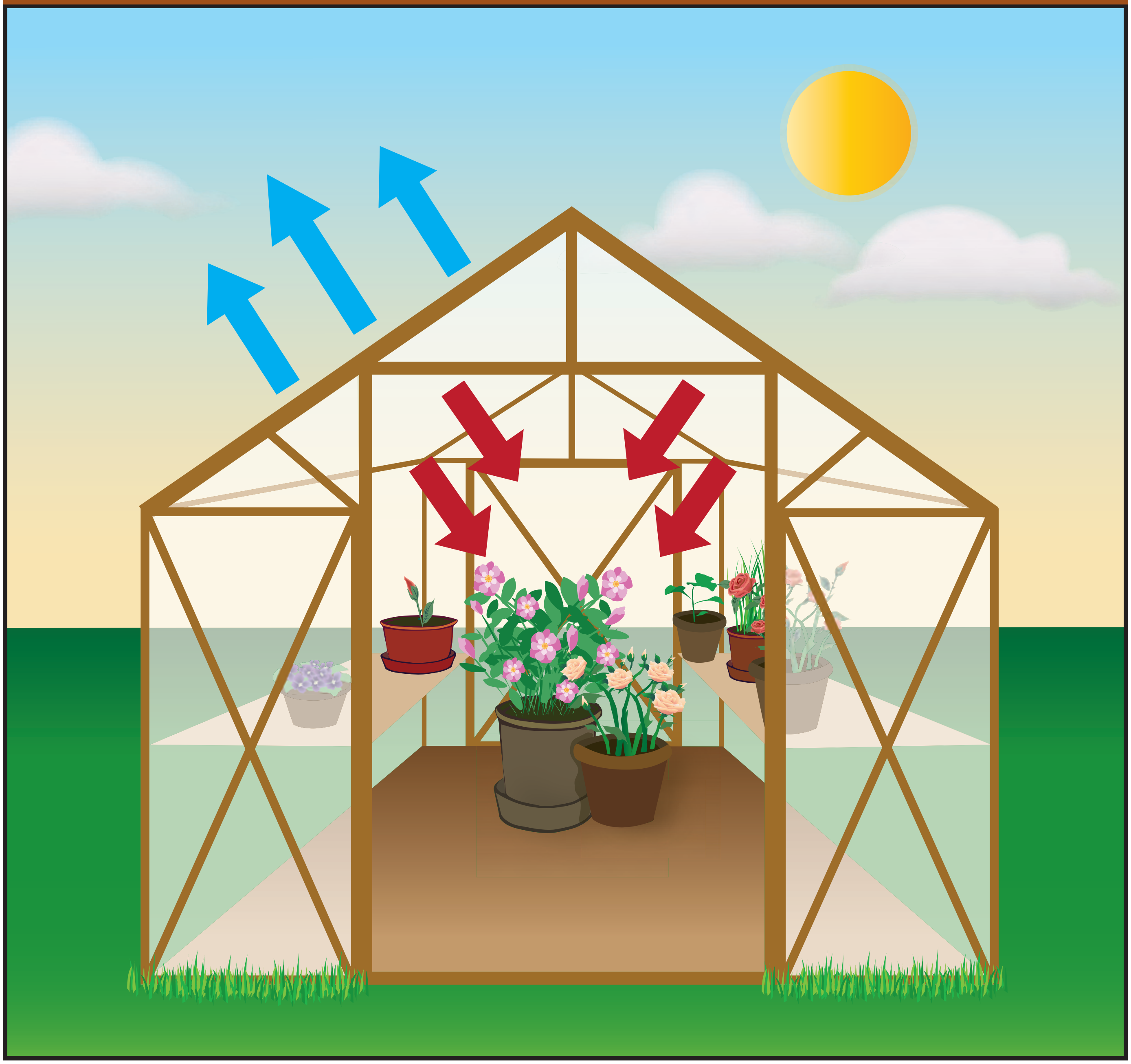
3. Complete the Venn diagram below by comparing a gardener's greenhouse to Earth's "greenhouse." How are they similar? How are they different? (10 points)



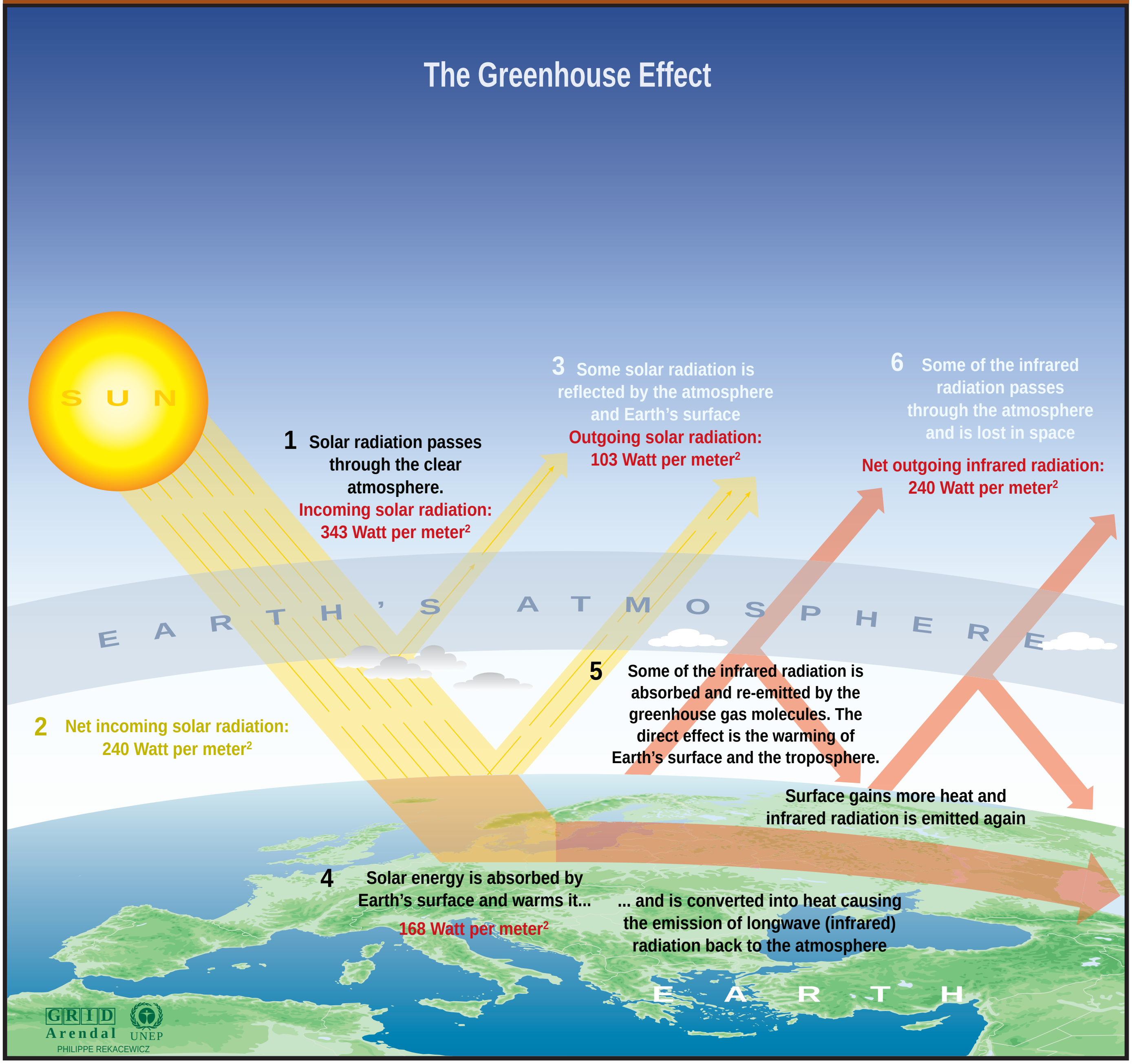
Atmospheres of Earth, Venus, and Mars

	Earth	Venus	Mars
			
Carbon Dioxide (CO_2)	0.030 %	96.500 %	95.000 %
Nitrogen (N_2)	78.000 %	3.500 %	2.700 %
Oxygen (O_2)	21.000 %	Trace	0.130 %
Argon (Ar)	0.900 %	0.007 %	1.600 %
Methane (CH_4)	0.002 %	0 %	0 %
Nitrous Oxide (NO_2)	Yes	No	Yes
Water Vapor	Yes	No	No

A Greenhouse



Earth's Greenhouse



Name: ______________________

Complete the following table based on the class discussion. (5 points each)

GHGs	Sources and Sinks
Water vapor	**Sources:** ____ ____ ____ **Sinks:** ____ ____ ____ **Human influences:** ____ ____ ____ ____ ____
Carbon dioxide	**Sources:** ____ ____ ____ **Sinks:** ____ ____ ____ **Human influences:** ____ ____ ____ ____ ____

Name: ______________________________

GHGs	Sources and Sinks
Methane	**Sources:** ____________________ ____________________ ____________________ **Sinks:** ____________________ ____________________ ____________________ **Human influences:** ____________________ ____________________ ____________________ ____________________ ____________________
Nitrous oxide	**Sources:** ____________________ ____________________ ____________________ **Sinks:** ____________________ ____________________ ____________________ **Human influences:** ____________________ ____________________ ____________________ ____________________ ____________________

Name: ______________________________

GHGs	Sources and Sinks
Other GHGs	**Sources:** ______________________________ ______________________________ ______________________________ **Sinks:** ______________________________ ______________________________ ______________________________ **Human influences:** ______________________________ ______________________________ ______________________________ ______________________________ ______________________________

Water Vapor: Sources and Sinks of GHG

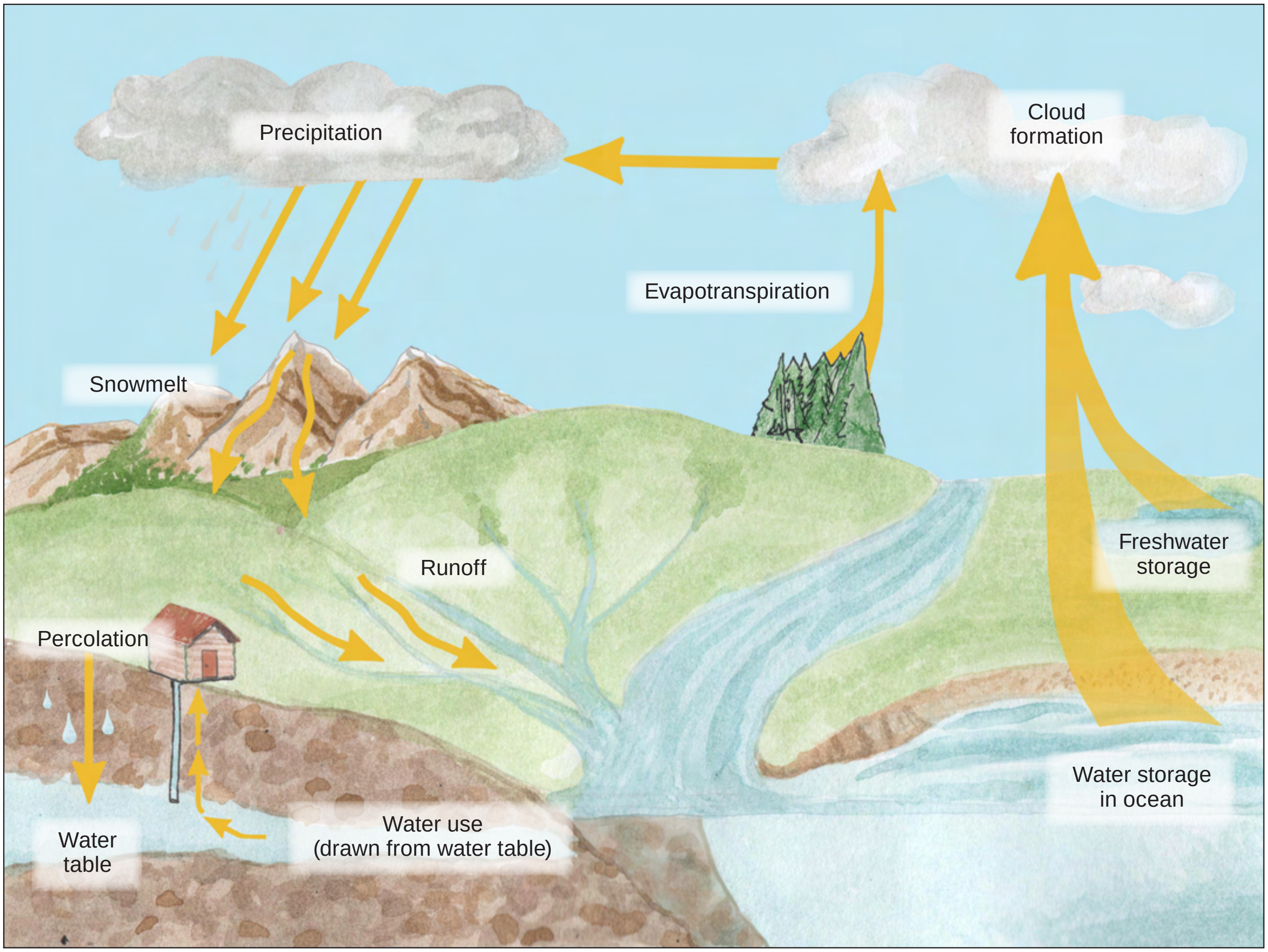
Water vapor in our atmosphere is an important greenhouse gas (GHG). On a cloudy day we can see evidence of the amount of water vapor in our atmosphere. During a heavy rainstorm—and especially during a hurricane—it is easy to see that our atmosphere is a huge reservoir of water vapor.

Water vapor is one of the greenhouse gases that is present around the planet and helps reflect heat back to Earth's surface keeping it within the atmosphere. Water vapor has a bigger influence on Earth's climate than any of the other greenhouse gases.

Why do scientists think it is so important? Water vapor is the most abundant greenhouse gas on Earth. As a result, it is a very effective absorber of infrared radiation.

The water cycle is the major natural process that influences the amount of water vapor in the atmosphere, although it is evaporation that turns liquid water into a gas. Water evaporation from the ocean produces about 67% of the Earth's water vapor. Ongoing evaporation helps cool the ocean (as heat is removed from the ocean's surface water molecules to create gaseous water molecules). Without this natural process, the ocean would heat up and in turn cause global air temperatures to rise. Evaporation from lakes and other bodies of water also occurs, but because oceans cover about 71% of our planet, most water vapor comes from the ocean reservoir.

Ocean waves



Discuss the following with your group:

- Water vapor sources: Where does water vapor in the atmosphere come from?
- Water vapor sinks: What removes water vapor from the atmosphere and stores it for a long time?
- Which human activities could cause more or less water vapor to be in our atmosphere?

Carbon Dioxide: Sources and Sinks of GHG

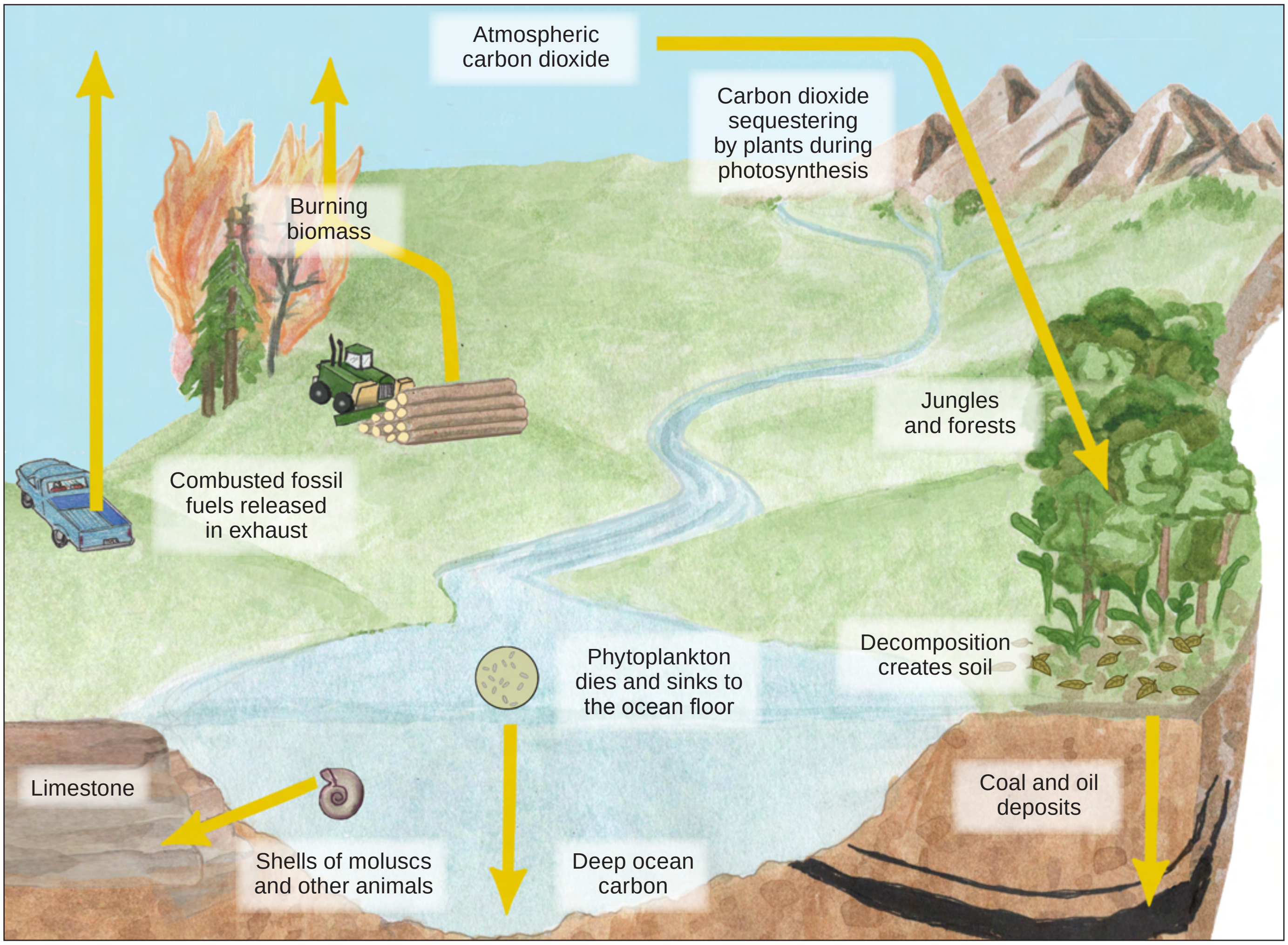
Carbon dioxide (CO_2) is a greenhouse gas (GHG) that can be found in our atmosphere. Carbon exists in all living organisms and is useful as a nutrient for growth and reproduction. All living things store carbon. Plants take up CO_2 during photosynthesis and convert it into biomass (plant matter). Long-lived plants, such as trees, are natural carbon sinks. Forest fires release carbon, stored as wood or woody vegetation, into the atmosphere. When people cut trees for use as a building material or in furniture, the carbon stored as wood stays stored indefinitely unless it decomposes or burns.

Short-lived plants, such as grasses, annual crops like corn, wheat, tomatoes, and other plants, take up carbon dioxide during growth and release this same carbon dioxide back to the atmosphere or to the soil when they die in the fall. People and animals consume plants harvested by farmers and their bodies convert carbon from the plants into carbohydrate energy needed for growth and reproduction.

Wind and wave action cause atmospheric carbon dioxide to mix into the ocean, where it becomes dissolved CO_2. Some organisms can convert carbon dioxide into calcium carbonate, the main ingredient in shells and skeletons. The ocean are home to vast numbers of shelled organisms. Because shells and skeletons are so hard and heavy, when organisms with shells or skeletons die, their bodies settle to the ocean floor or are washed ashore by tides where they accumulate on the beach. The shells and skeletons that sink to the deep ocean create a real carbon sink. When shells are compressed under weight (such as the weight of the entire ocean), they become carbonate rock (such as limestone and marble). These rock formations are a big reason why the ocean is a carbon sink. Weathering and temperature changes break apart carbonate rock and release the carbon locked inside. This happens when rocks are exposed when ocean levels change due to tectonic activity.

When terrestrial organisms (plants and animals) die, microorganisms in the soil break down or decompose the dead material. Some of the carbon is released to the atmosphere as carbon dioxide, and some remains in the soil. In this

Logs



way, soils are a sink for carbon. Soils store more carbon than the atmosphere or living organisms.

Fossil fuel deposits (oil, coal, and natural gas) are ancient plants that did not decompose completely and were compressed underground or under the ocean. This compression created a concentrated form of carbon that, when burned, releases stored energy.

Discuss the following with your group:

- Carbon dioxide sources: Where does carbon dioxide in the atmosphere come from?
- Carbon dioxide sinks: What removes carbon dioxide from the atmosphere or stores it for a long time?
- Which human activities could cause more or less carbon dioxide to be in our atmosphere?

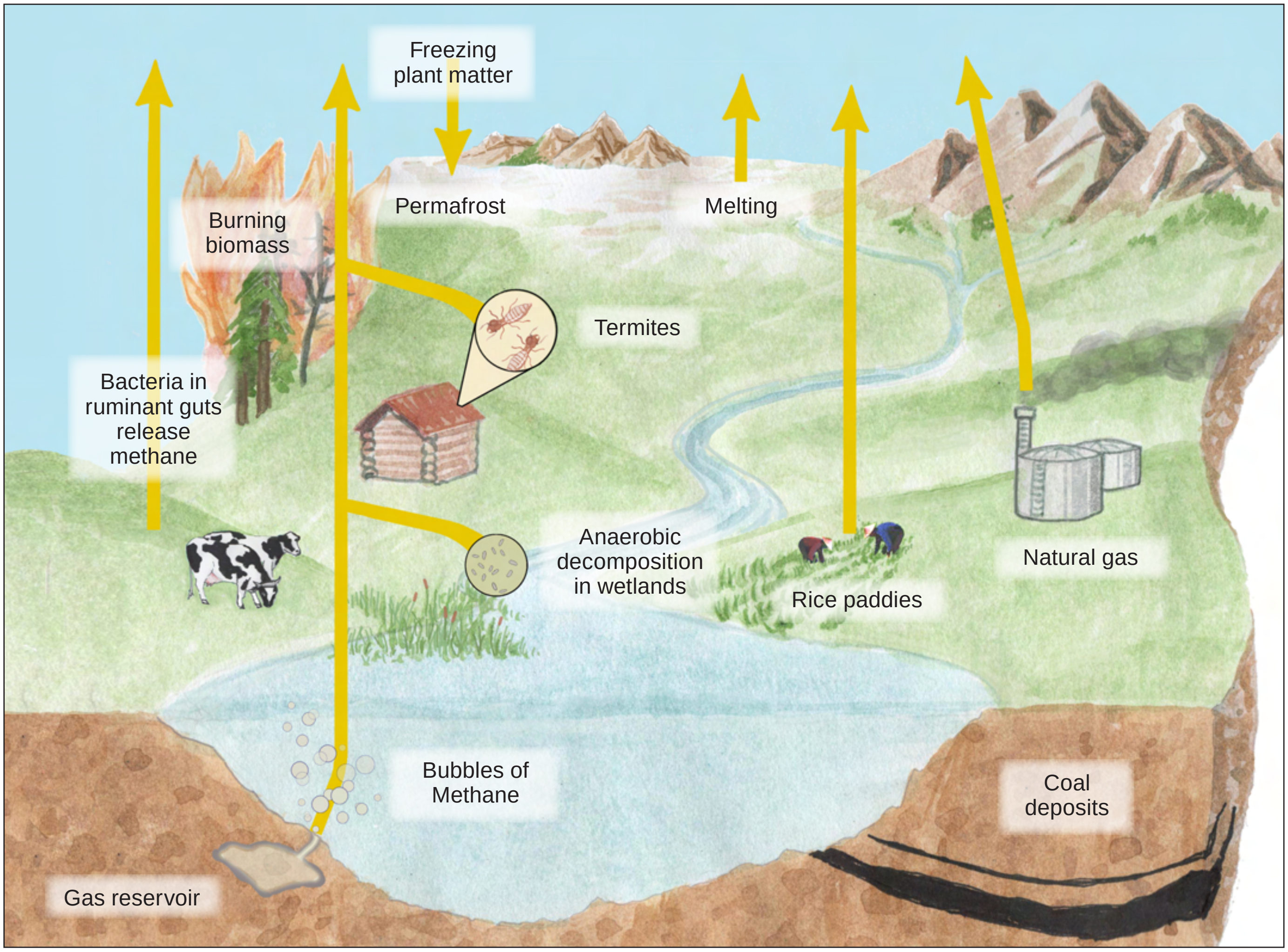
Methane: Sources and Sinks of GHG

Methane (CH_4) is a greenhouse gas (GHG) in our atmosphere. It is a carbon-based gas, like CO_2. Methane is produced when animal waste or dead organisms decompose. Methane gas is a type of fossil fuel. Millions of years ago, plants that were only partially decomposed were buried underground. Under pressure, the carbon from these once-living organisms turned into methane gas. People burn methane as a source of energy.

Methane is also produced by the decomposition of plants in wetlands. If you have ever gotten stuck in the muck along the edge of a pond, you have probably smelled the stinky gas that was released when your foot finally slurped out of the muck. That smell was methane. Other moist soils—even frozen ones—form methane, too. Moist soils that are frozen for at least two years in a row are called permafrost. Permafrost exists at high latitudes and in alpine areas (high in mountains). Specially adapted low-growing plants can live in permafrost. When these plants die, the carbon stored within the plant material becomes trapped within the permafrost as methane. When permafrost melts, it releases methane into the atmosphere.

Forests take up carbon dioxide from the atmosphere and, through photosynthesis, convert it into plant material, or wood. Some of this carbon is converted to methane, and when trees respire, they release some of that methane into the atmosphere. Trees are long-living plants and their woody growth acts as a sink of both carbon dioxide and methane.

Forest fire



Because forests are a sink for methane, when they burn they can release methane to the atmosphere.

Some animals can also release methane gas. Ruminants, such as cattle, goats, sheep, bison (buffalo), giraffes, and deer, have a special process for digesting grass and the other plant material they eat. Bacteria work as part of this digestive process breaking down plant matter and releasing methane as animals exhale and emitting gas. As termites consume wood, their digestive processes create methane in a similar manner. The amount of methane cows and termites produce is not insignificant.

Discuss the following with your group:

- Methane sources: Where does methane in the atmosphere come from?
- Methane sinks: What removes methane from the atmosphere or stores it for a long time?
- Which human activities could cause more or less methane to be in our atmosphere?

Nitrus Oxide: Sources and Sinks of GHG

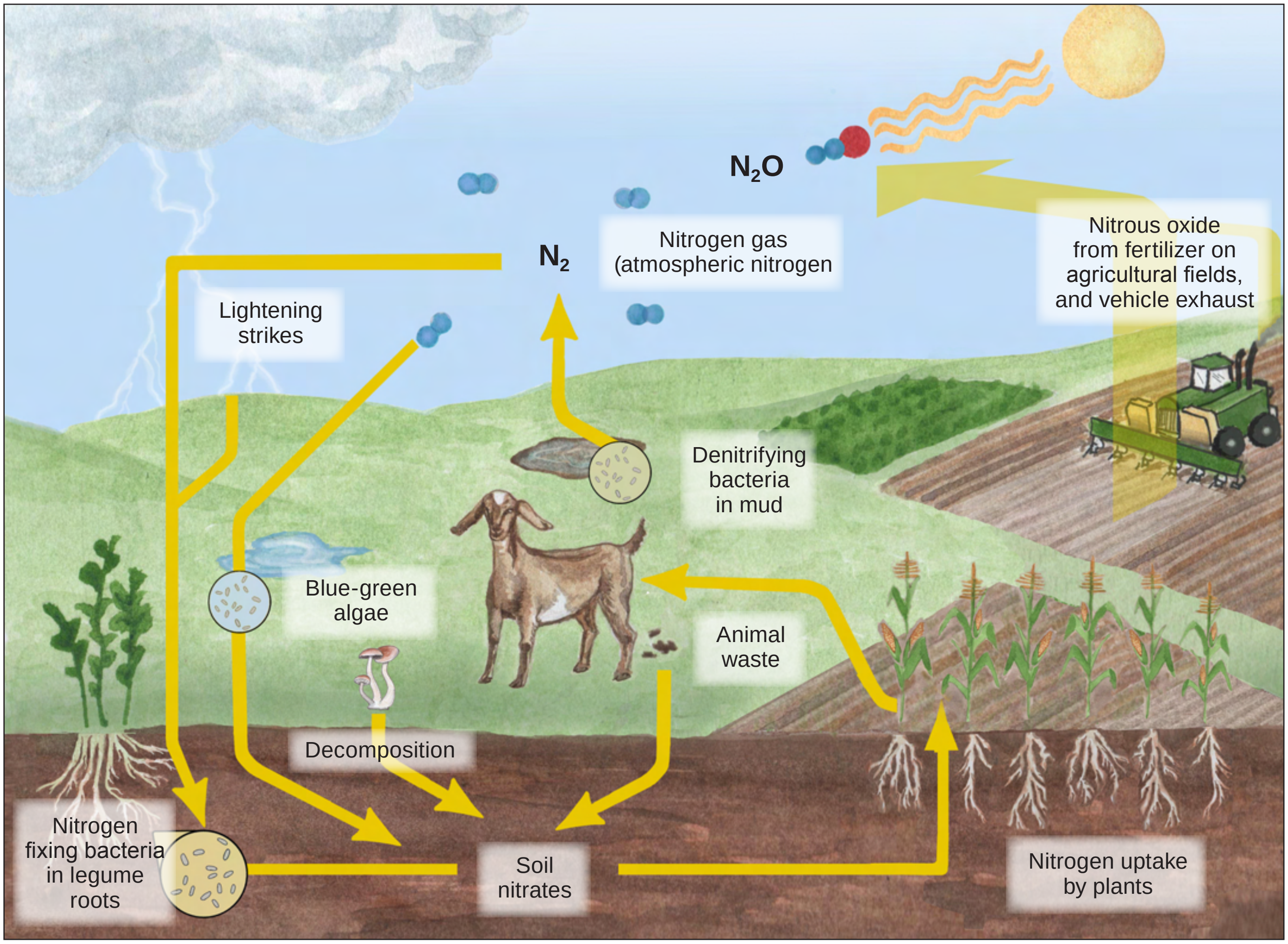
Nitrogen (N_2) is the most common gas in the atmosphere, where it comprises about 78% of the gas by volume. Nitrogen, like carbon, is involved in a cycle, where, in different chemical forms, it moves between the atmosphere, ocean, fresh water, soil, plants, and animals. It is released into the soil when animal waste or dead plants and animals decompose.

Nitrogen atoms are found in many different molecules including nitrous oxide (N_2O), in which two atoms of nitrogen combine with one atom of oxygen. Nitrous oxide, which has very different chemical characteristics from pure nitrogen, is one of the atmosphere's important greenhouse gases (GHG). Photolytic reactions (light-driven reactions) in the stratosphere are the major N_2O sink in the atmosphere.

Nitrous oxide is produced and released naturally, and from human-related sources. About 66% of the largest human-related sources are associated with soil management for agriculture. The use of nitrogen-based fertilizers to improve the soil on farms is the largest contributor to this problem. Other human-related sources of nitrous oxide include sewage treatment, farm animals' waste products, burning of fossil fuels, and production of chemicals like nitric acid. The principal natural sources of nitrous oxide are decomposition and bacterial action in soil. Rather than just using oxygen for respiration—many species of bacteria can use nitrates, a nitrogen-containing molecule—in the soil as the basis for respiration. This process, called "denitrification," releases nitrous oxide into the atmosphere.

Recent research indicates that concerns about nitrous oxide are of greater importance than was once believed. The amount of nitrous oxide gas in the atmosphere increased during the 20th century

Sewage treatment plant



and that increase is continuing today. The annual increase in atmospheric nitrous oxide has been about 0.25% each year during the last century. Although this seems like a very small number, it is important in comparison to other GHGs because of its potential to increase global temperatures. Scientific research indicates that, over a 100-year period, nitrous oxide has a 300 times greater "global warming potential" than carbon dioxide.

Discuss the following with your group:

- Nitrous oxide sources: Where does nitrous oxide come from?
- Nitrous oxide sinks: What removes nitrous oxide from the atmosphere or stores it for a long time?
- Which human activities could cause more or less nitrous oxide to be in our atmosphere?

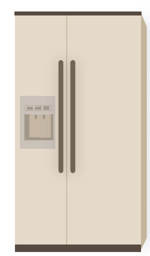
San Luis Reservoir, California

Other Greenhouse Gases

Sources: Humans

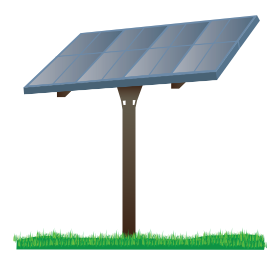
HCFCs, CFCs





Found in aerosol sprays (spray paint, cooking spray), dry cleaning fluids, air conditioning, refrigeration and more.

Perfluorocarbons
Sulfer hexafluoride
Nitrogen trifluoride (NF_3)

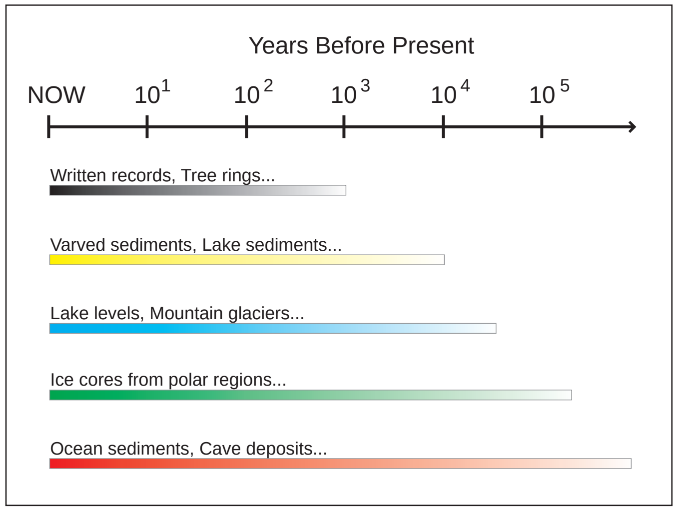
Used in the medical and electronic fields, as well as processing and manufacturing of semiconductors.

Sinks: Atmosphere

What Can Ice Tell Us About Past Climate?

Imagine finding a time capsule containing clues of what Earth was like during the last ice age. Now, imagine finding hundreds of thousands of time capsules that date back 420,000 years, or even a million years! What a story these capsules could tell! Scientists who study past climates—paleoclimatologists have found such time capsules.

Paleoclimatologists reconstruct past temperatures and climates by using fossil records from nature, such as rings from trees and skeletal remains from tropical coral reefs. When we want to know about the past before there were any trees or coral, we need to study things that are even older. Polar ice sheets are made from layers upon layers of packed snow. Using hollow steel tubes, scientists drill and extract ice cores that contain ice layers that are more than 700,000 years old! These scientists can also extract ancient ocean sediments.



Timelines for paleoclimate reconstruction

What Can Ice Tell Us About Past Climate?

When snow forms, it crystallizes in the atmosphere around tiny particles, which fall to the ground with the snow. The snow crystals become frozen time capsules, storing whatever was floating around in the atmosphere at the time. Dust, volcanic ash, smoke, pollen, and radioactive isotopes from solar radiation in the snow crystals provide clues about the climate and environmental conditions when the snow formed.

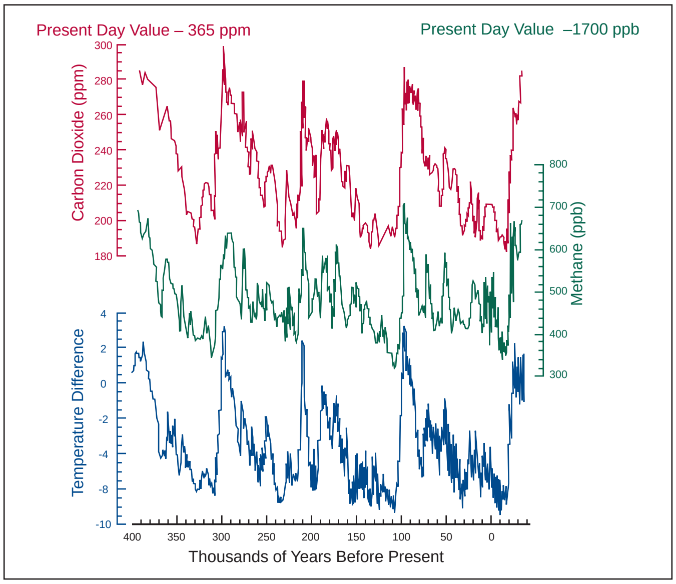
Each year new snow settles on the ice, forming layers. The air bubbles trapped in this ice become an annual sealed record of the gases and particles in the atmosphere.

Digging Into Ice

Records of methane gas, for example, provide clues about how many wetlands covered the planet in the past. (Wetlands are a source of methane.) Similarly, records of the amount of carbon dioxide in ancient air bubbles can give us a picture of the number of living organisms at a given time. Dust records tell us approximately how many deserts covered the planet; pollen records show which plants and trees lived in the past. All of these clues help us understand what the climate was like over time. The clues can tell us about temperature, precipitation, and the chemical composition of the lower atmosphere. Paleoclimatologists usually drill ice cores in Greenland and Antarctica, where the oldest ice sheets remain. Other times they drill into glaciers on different continents.

Name: ______________________________

Studying proxy data shows us that throughout much of Earth's geologic past, changes in climate occurred over long periods. The scale of these changes was generally large whether the transition was from periods of cold to cool to warm, or the opposite. Respond to the questions using the information from the ice core graph below.



The data to the left is from an ice core drilled at Vostok, Antarctica. The red line (top) shows the concentration of carbon dioxide there. The green line (center) shows the concentration of methane at the site. The blue line (bottom) shows the average temperature, plotted as the difference from today's average temperature (represented by the 0° C line).

1. Describe what happens to carbon dioxide and methane over time. How does temperature data compare to changes in these greenhouse gases? Explain your answer. (3 points)

____

____

____

____

2. What is the overall pattern we can draw from this data? How would you describe this pattern? (3 points)

____

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____

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Name: ______________________________

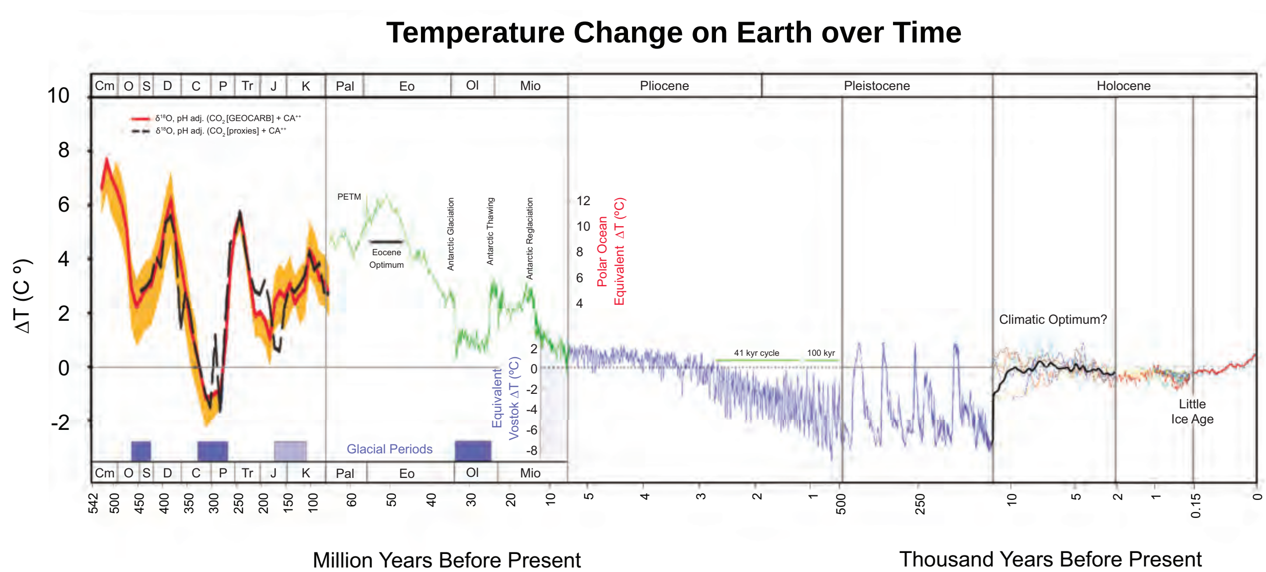
3. How does the concentration of methane and carbon dioxide from 330,000 years ago compare with current concentrations of these gases? (3 points)

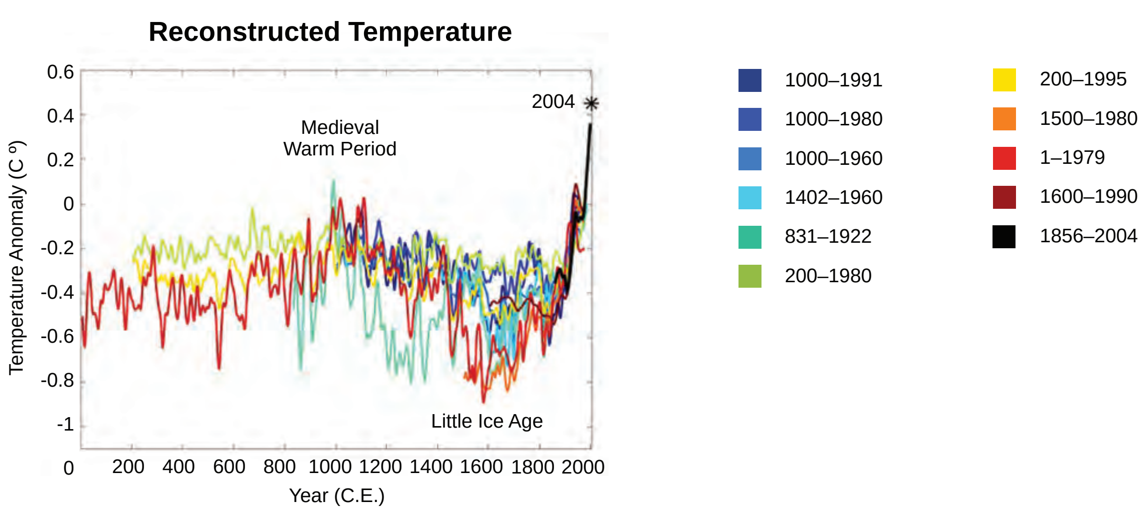
4. Were the concentrations of methane and carbon dioxide ever higher than they are today? (3 points)

5. Based on this data, would you conclude that temperatures are warming or cooling? (3 points)

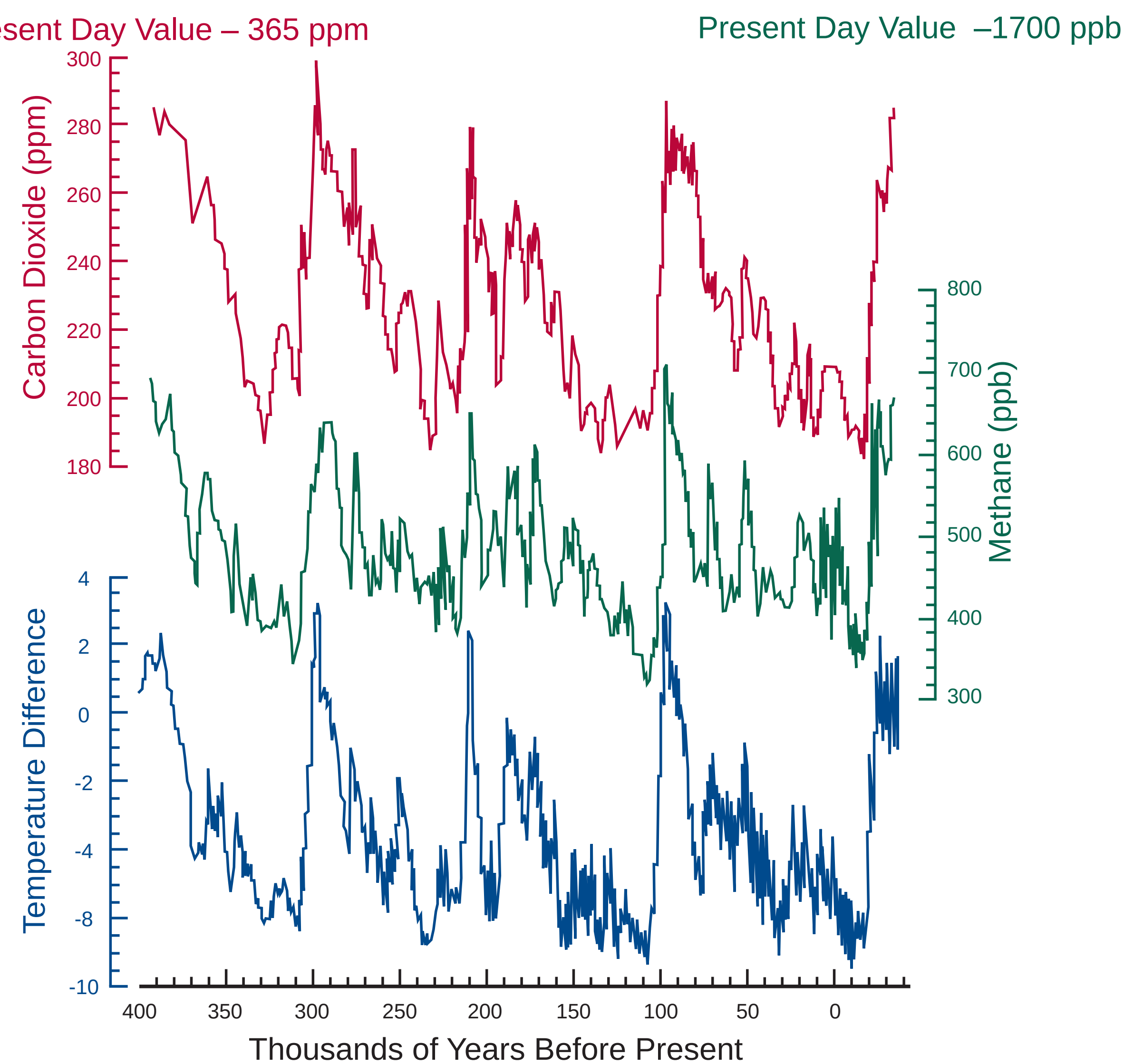
6. Given ancient ice core data and your understanding of the greenhouse effect, what conclusions can you draw about climate change? (10 points)

Temperature Change on Earth over Time

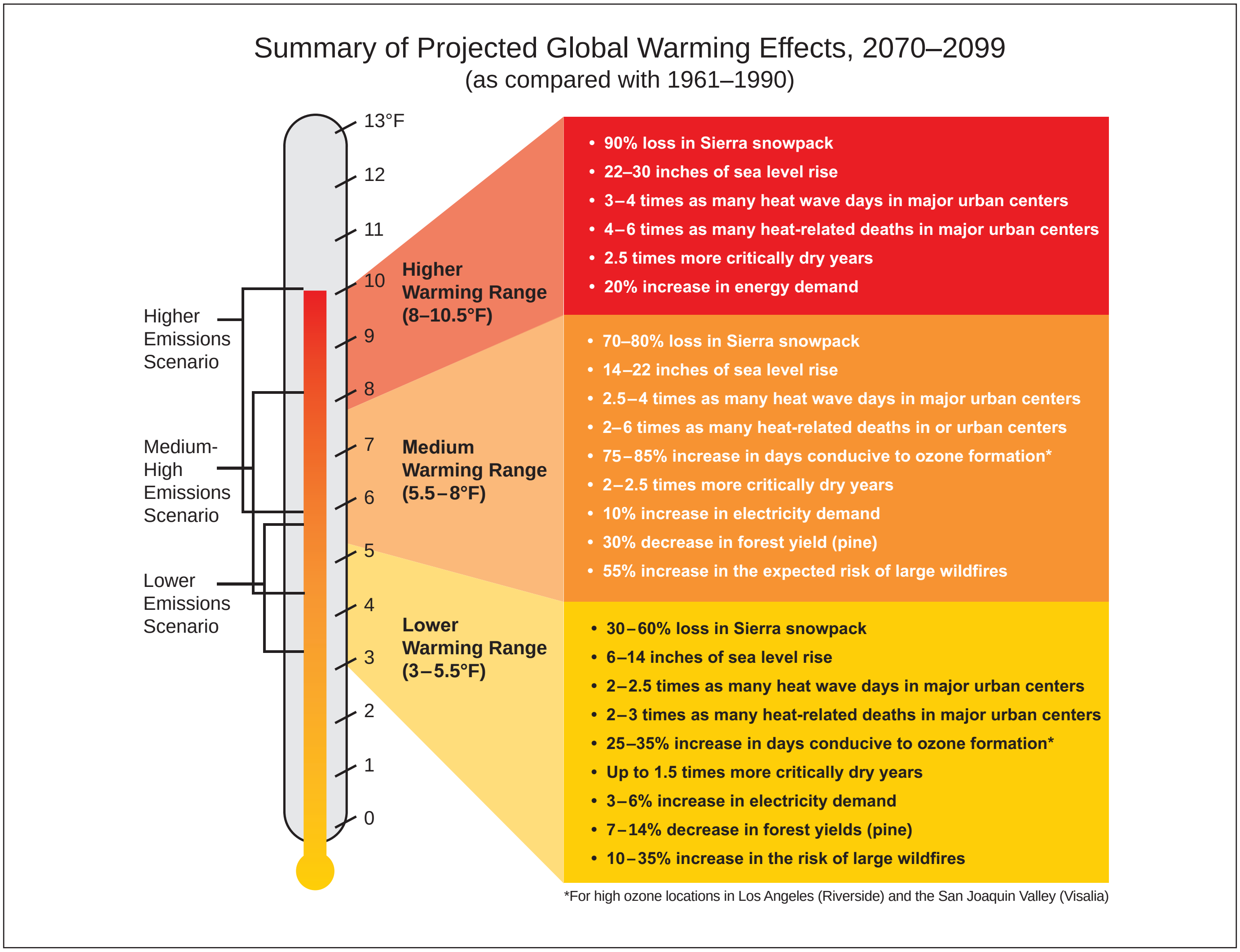




Vostok Ice Core Data



Name: ______________________________



This image is based on computer climate model projections using three different emission scenarios.

Lower Emissions Scenario

This scenario predicts that global population growth will slow and people will switch from using fossil fuels to technologies that are cleaner and greener. In this scenario, greenhouse gas emissions peak by 2050 and then decline and carbon dioxide doubles by 2100 from preindustrial levels.

Medium-High Emissions Scenario

This scenario projects continuous population growth and the introduction of some new technologies to replace fossil fuels. In this scenario, greenhouse gas emissions increase throughout the century and CO_2 emissions triple by 2100 from preindustrial levels.

High Emissions Scenario

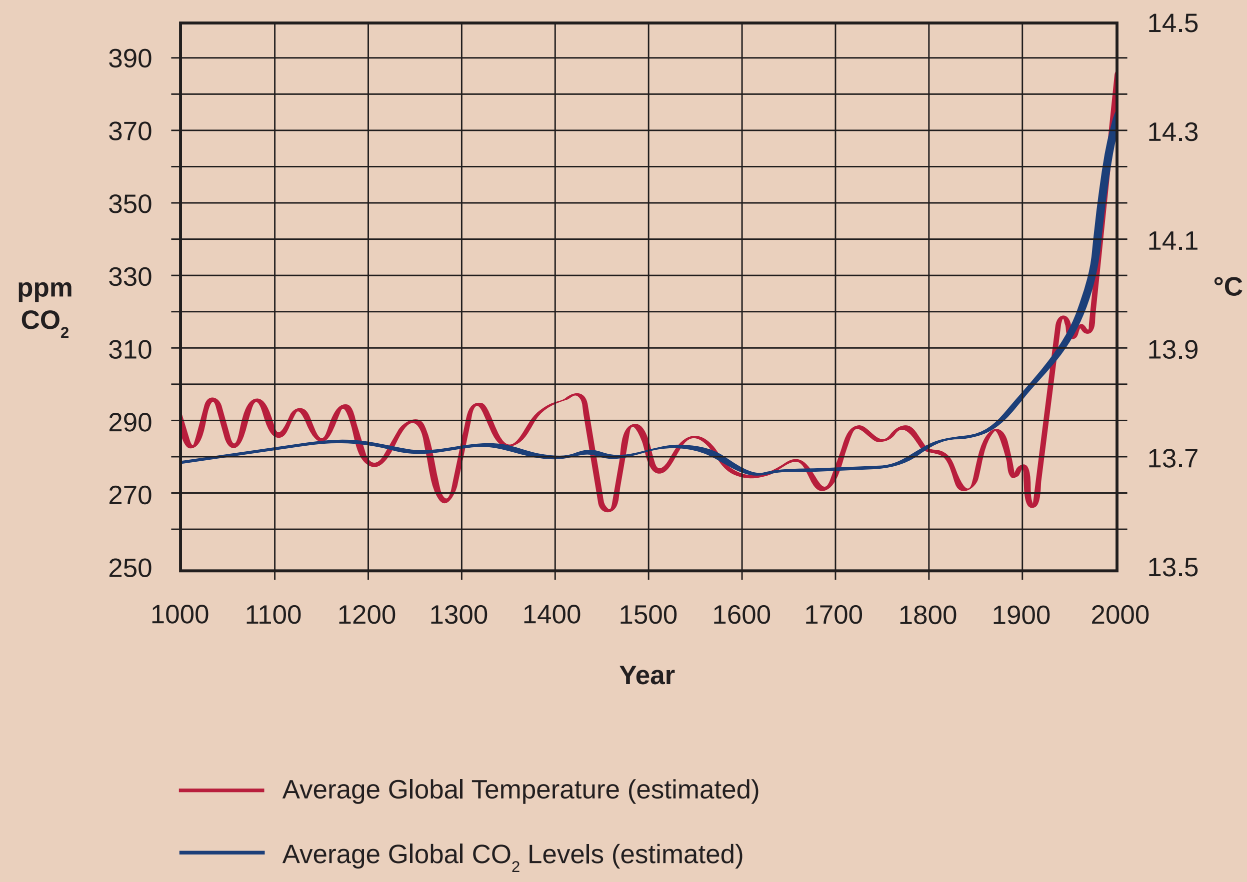
This scenario predicts a world in which fossil fuels are a main source of energy. In this scenario, new fossil fuel-free technologies are not introduced until the end of the century. Greenhouse gas emissions more than triple by 2100 from preindustrial levels.

Name: ______________________________

Think and Write

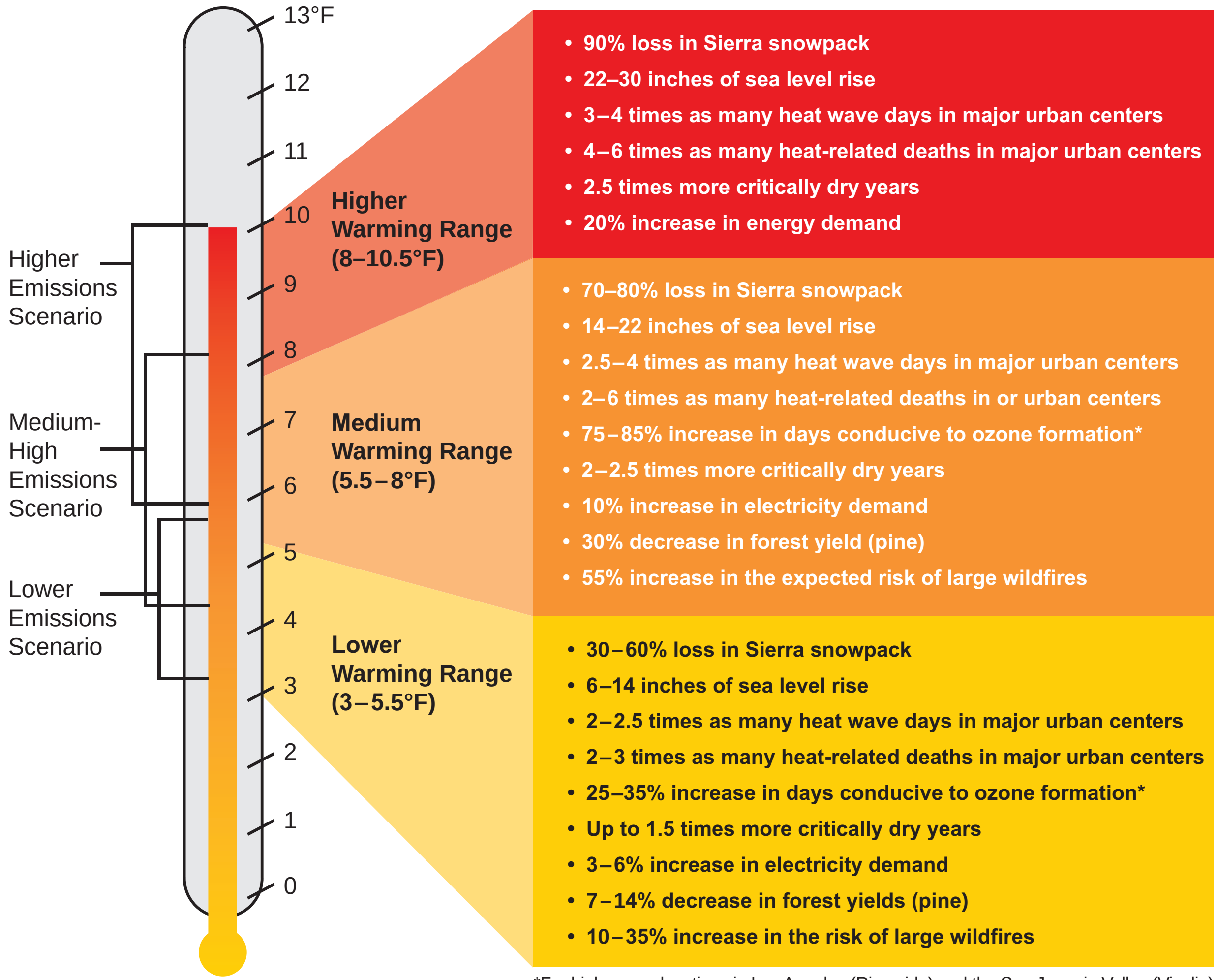
What is global climate change? What do people hypothesize is the cause of it? How could global climate change affect our human communities? (40 points)

Modern Global Temperatures and Carbon Levels



Projected Global Warming Effects in California

Summary of Projected Global Warming Effects, 2070–2099
(as compared with 1961–1990)



*For high ozone locations in Los Angeles (Riverside) and the San Joaquin Valley (Visalia)

California's Global Warming Solutions Act of 2006

The Global Warming Solutions Act of 2006, also known as Assembly Bill 32 (AB 32), was written by California AssemblySpeaker Fabian Núñez and Assemblywoman Fran Pavley. Below are portions of the speeches given by Governor Arnold Schwarzenegger and Speaker Núñez during the signing of this landmark legislation on September 27, 2006.

California State Assembly chamber

Goals of the Act:

- Reduce statewide greenhouse gas emissions to 1990 levels by the year 2020.
- Establish regulations that will uphold and enforce these goals.
- Identify the most cost-effective strategies and methods to reduce GHGs, including CO_2, methane, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

Timeline:

June 30, 2007

- Develop a list of "early action measures" that can be put into action before January 1, 2010.

January 1, 2008

- Inventory statewide emissions.
- Establish a statewide GHG emissions cap for 2020 based on emission levels in 1990.
- Adopt mandatory reporting rules for significant sources of greenhouse gases, such as power plants and various modes of transportation.

January 1, 2009

- Adopt a plan for reducing emissions from significant GHG sources that includes regulations (rules), market mechanisms, and other actions.

January 1, 2011

- Adopt regulations to reduce emissions of GHGs that are the most cost-effective and based on the best technology available.

Governor Schwarzenegger described the goals of this legislation:
"We will reduce carbon emissions back to the 1990 level by the year 2020. That means that we will reduce carbon emissions by 25 percent by the year 2020. And this is only the beginning, because by 2050 we will reduce emissions by another 80 percent. We simply must do everything that we can in our power to fight global warming before it is too late."

Fabian Núñez described why this bill was written and why this legislation would be successful in California:
"You know, what's amazing about this bill, it's the first of its kind in the nation, and it comes at the right time. In a recently published report by NASA's Goddard Institute, it was discovered that the earth has reached its warmest point in almost 12,000 years. As scientists have been telling us for decades, we know that now this report reaffirms the link between pollution that man puts into the atmosphere and this warming trend we call global warming. AB 32 is going to give California the tools to reverse this destructive course and preserve our planet for our children and for generations to come.

Many people have asked us, why do this in California when we should be doing this nationally? And let me tell you, California should be championing this thing, because it's a pretty simple response. Our state is the best state to start this, and it's also the most capable state. As the birthplace of microprocessors and the home of some of the finest research scientists in the entire world—of course, in between all of that you have all of the patents, the researchers, and the Nobel Prize winners—you could almost say that indeed it is California's destiny to be the first state in the nation to take such bold steps to combat global warming.

Today we are telling the world that California has the courage, the know-how, and the advantage to turn the tide on this creeping disaster. My hope is that other states, other countries as well as our own, are going to work with us and find the benefit in this legislation, to follow us in this great journey to protect our planet. And California alone—think about—over the next 14 years, we're going to reduce 174 million tons of carbon emission—174 million in a 14-year period. Now, that is something to be proud of.

And lastly, I want to say, as the saying goes, necessity is the mother of invention. We're going to send a clear message through the market to spur entrepreneurs to deploy clean technologies in California. We believe that ultimately California is going to pave the way for the next generation of a high-tech green economy for this state, a high-tech economy that is going to translate into tens of thousands of jobs for Californians as well as billions and billions of dollars of investment. You can't get much better than that."

Excerpts from the speech given by Governor Arnold Schwarzenegger and House Speaker Fabian Núñez on September 27, 2006.
Source: ***http://gov.ca.gov/press-release/4111/***

Read over the timeline below to identify the relationship between scientific discoveries and policies and decisions humans have made about climate over the past three decades.

Discovery	Policy or Decision
1979 U.S. Department of Energy reports GHGs increasing in the atmosphere.	**1979** First World Climate Conference held in Geneva. It is sponsored by the World Meteorological Organization, a specialized agency of the United Nations.
1985 Ice core data shows climate goes up and down along with GHGs in the atmosphere. Climate models predict global temperature will increase 2.7–8.1° F (1.5–4.5° C) over the next 100 years. Scientists predict rising sea levels and changes to world ecosystems.	
1987 Global temperatures shown to have risen 0.9° F (0.5° C) in a century. James Hansen, NASA chief climatologist, testifies to Congress on the hazards of climate change and global warming.	
1988 NASA reports there are indications of "global warming."	**1988** The Intergovernmental Panel on Climate Change (IPCC) established by the United Nations.
	1990 The second World Climate Conference is held, again in Geneva. The IPCC issues its first report on the dangers of climate change.
1991 Data from Mount Pinatubo eruption shows effect of particulate matter and increased CO_2 levels in the atmosphere.	**1992** IPCC calls for action on climate change: scientists develop the Framework Convention on Climate Change to address human interference with the Earth's climate system.

Discovery	Policy or Decision
1993 Ice core data shows climate can change in shorter periods of time (decades, rather than millions of years) than previously understood.	**1993** United Nations and New York State create the Cities for Climate Protection Campaign.
	1994 Alliance of Small Island States demands the world cut GHG emissions by 20% by 2005, because these countries will be threatened first by rising sea levels.
1995 IPCC reports "global warming likely due to human activities."	**1995** Meeting of the members (countries) of the United Nations Framework Convention on Climate Change (UNFCCC) sign the Berlin Mandate to cut worldwide GHG emissions.
	1996 Meeting of the members (countries) of the United Nations Framework Convention on Climate Change (UNFCCC) sets "legally binding emissions targets" for developed and developing countries.
	1997 Kyoto Protocol established to set GHG emission limits for participating countries.
1999 Ice core data shows 1990s to be hottest decade in 1,000 years.	
2001 Hottest year in human history. IPCC announces that "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities." Average ocean temperature is increasing.	**2001** United States rejects Kyoto Protocol, saying it will hurt the U.S. economy.

Discovery	Policy or Decision
2002 New high global temperature set.	**2002** California signs the nation's first law limiting GHG emissions from vehicles. Eighteen other states establish Clean Energy States Alliance to reduce GHG emissions. Japan, European Union member states, and Canada sign Kyoto Protocol.
2003 Ice sheets in West Antarctica and Greenland collapse.	**2004** CARB votes to cut vehicle GHGs by 30% by the 2016 model year, but USEPA prevented this action at that time. Twelve other states join Clean Energy States Alliance.
2005 Hurricane Katrina causes debate about climate change and its relationship to intense storms. CO_2 levels in atmosphere reach 380 parts per million (ppm).	**2005** International governments and localities take efforts to reduce GHGs. New Jersey classifies CO_2 as a pollutant. California sets aggressive emission reduction goals and other states follow. **2006** Western Governors Association files a lawsuit against the U.S. Environmental Protection Agency (USEPA) about new fuel economy standards for SUVs, saying they are too low. California passes Global Warming Solutions Act (AB 32).
2007 IPCC reports CO_2 levels are at 382 ppm, and average global temperature is 58.1° F (14.5° C). IPCC states "global warming is 'very likely' caused by human activities." Arctic sea ice reaches lowest areal extent since measurements began. Former U.S. Vice President Al Gore and the IPCC are given Nobel Prizes for their work in communicating the threat of global warming.	**2007** Other states adopt vehicle emissions standards. The Climate Registry is established to share information about reducing GHGs and help countries and businesses calculate and register their carbon footprints.

Discovery	Policy or Decision
2008 Ice (160 square miles of it) breaks off the Wilkins Shelf along the Antarctic coastline.	**2008** Governors of 18 states sign Declaration on Climate Change (**http://www.pewclimate.org/node/5893** NJ, CT, CA, KS, AZ, CO, DE, FL, IL, MD, MA, ME, MI, NM, NY, OR, VI, and WA) asking for more action on climate policy at both state and federal levels. **2009** A meeting of the members (countries) of the United Nations Framework Convention on Climate Change (UNFCCC) is scheduled to be held in Copenhagen, Denmark. The goal is to develop a new protocol to address climate change as the Kyoto Protocol expires.

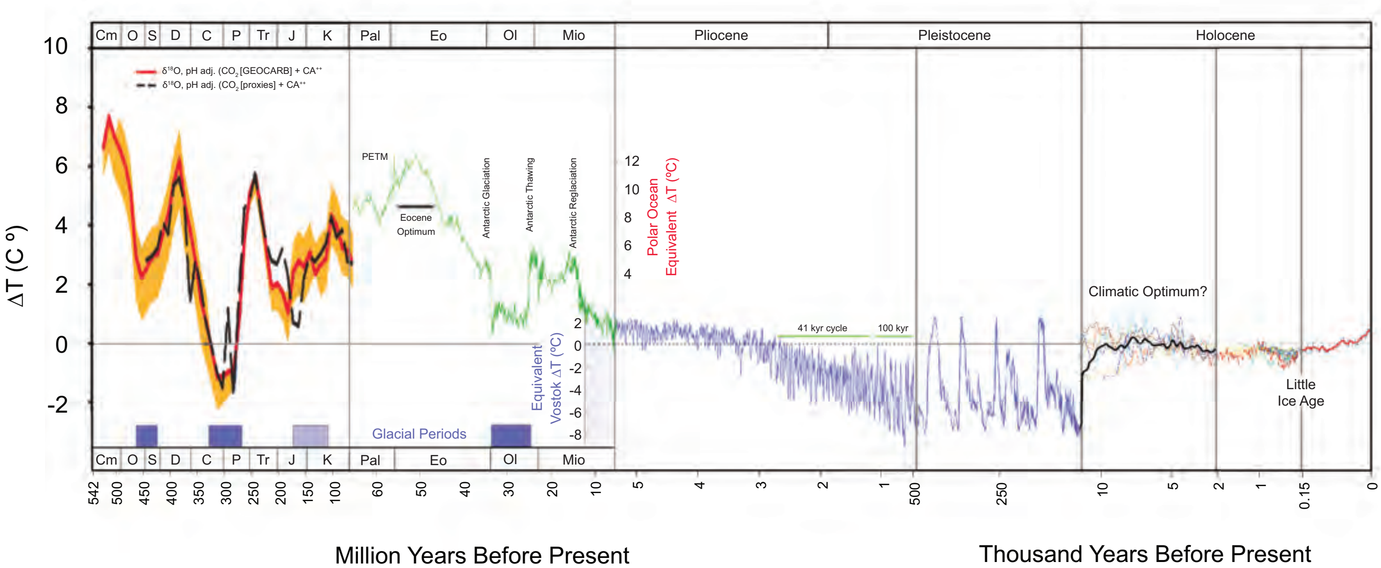
Name: ______________________________

The table below shows how temperatures on Earth have changed over 542 million years.

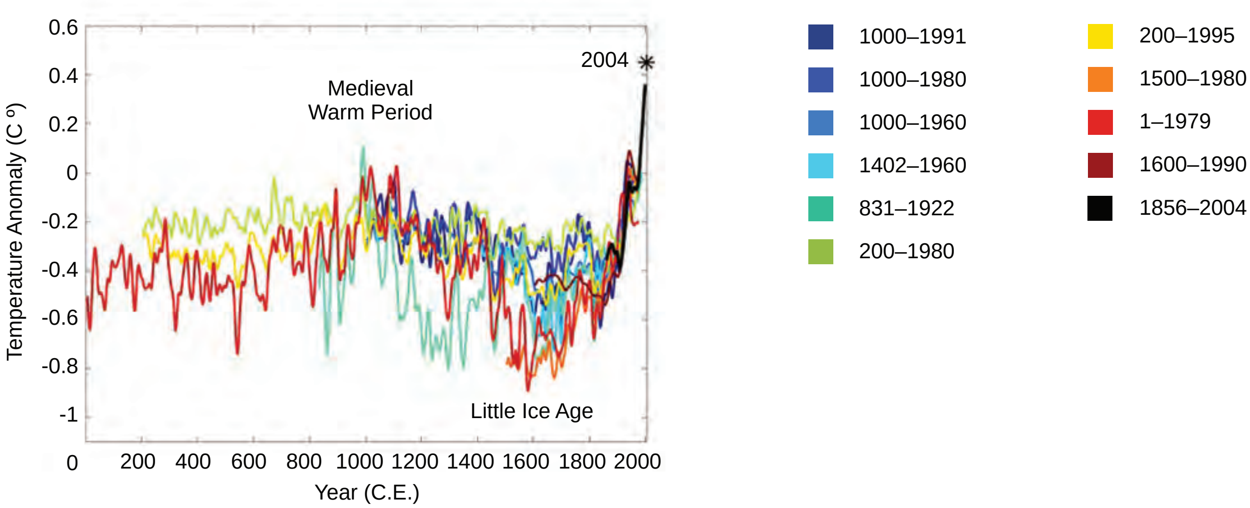
"Temperature Anomaly" and "ΔT" mean the same thing (Δ stands for "change in" and T stands for "temperature"). Both of these graphs show how much the temperature changed at a certain time, not the actual temperature at that time.

As you can see, temperatures on Earth have changed many times over millions of years. The smaller graph shows a more detailed view of temperature changes over the past 2,000 years on Earth.

Temperature Change on Earth over Time



Reconstructed Temperature



Name: ______________________________

Think and Write

Consider how climate has changed in the past and the fact that climate is continuing to change. How could life be different in the future? What are some of the issues people need to consider when examining climate change?

Use information from ***California Connections: Climate Change in the Golden State*** and the graph on the previous page and to develop your answer.

Write your essay below. (40 points)

Credits

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Page 16	Earth's climate system – Celeste Dodge
Page 17	The greenhouse effect – Philippe Rekacewicz, UNEP/GRID-Arendal/Okanagan University College, Canada, Department of Geography, University of Oxford, School of Geography, United States Environmental Protection Agency (EPA), Washington; Climate Change 1995, The Science of Climate Change, Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), UNEP and WMO, World Meteorological Organization, Cambridge University Press, 1996 (http://maps.grida.no/go/graphic/greenhouse-effect)
Page 20	A greenhouse – Sarah Pinch/Creative Services, California State University, Sacramento
Page 21	Earth's greenhouse – Philippe Rekacewicz, UNEP/GRID-Arendal/Okanagan University College, Canada, Department of Geography, University of Oxford, School of Geography, United States Environmental Protection Agency (EPA), Washington; Climate Change 1995, The Science of Climate Change, Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), UNEP and WMO, World Meteorological Organization, Cambridge University Press, 1996 (http://maps.grida.no/go/graphic/greenhouse-effect)
Page 26	Water Vapor: Sources and sinks of GHG – Celeste Dodge
Page 28	Carbon Dioxide: Sources and sinks of GHG – Celeste Dodge
Page 30	Methane: Sources and sinks of GHG – Celeste Dodge
Page 32	Nitrous Oxide: Sources and sinks of GHG – Celeste Dodge
Page 34	Other greenhouse gases – Sarah Pinch/Creative Services, California State University, Sacramento
Page 35	Timelines for paleoclimate reconstruction – Adapted by Candi Mayfield/Creative Services, California State University, Sacramento from original by U.S. Geological Survey/U.S. Department of the Interior/USGS
Page 36	Vostok ice core data – Adapted by Candi Mayfield/Creative Services, California State University, Sacramento, from original by United Nations Environment Programme (www.unep.org/geo/ice_snow)

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Page 40	Projected global warming effects in California – Adapted by Candi Mayfield/Creative Services, California State University, Sacramento, from original by the Union of Concerned Scientists (www.climatechoices.org/impacts_overview)
Page 42	Modern global temperatures and carbon levels – Adapted by Rebecca Voorhees/Creative Services, California State University, Sacramento from original by Hanno/Wikipedia/D.M. Etheridge, L.P. Steele, R.L. Langenfelds & R.J. Francey (1998) as "Historical CO2 records from the Law Dome DE08, DE08-2, and DSS ice cores"/Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee, U.S.A. (http://cdiac.esd.ornl.gov/trends/co2/lawdome.html)
Page 43	Projected global warming effects in California – Adapted by Candi Mayfield/Creative Services, California State University, Sacramento, from original by the Union of Concerned Scientists (www.climatechoices.org/impacts_overview)
Page 50	Temperature change on Earth over time – Robert A. Rohde/Global Warming Art (http://www.globalwarmingart.com/wiki/Main_Page) Reconstructed temperature graph – Robert A. Rohde/Global Warming Art (http://www.globalwarmingart.com/wiki/Main_Page)

Map Credits

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